D 42722

UNCLASSIFIED

428722

Preliminary Copy

AF TECHNICAL REPORT NO. 6517, Part 3

DETERMINATION OF PHYSICAL PROPERTIES OF FERROUS AND NONFERROUS STRUCTURAL SHEET MATERIALS AT ELEVATED TEMPERATURES

D. E. Miller
Armour Research Foundation
of Illinois Institute of Technology
Chicago 16, Illinois

December 1953

WRIGHT AIR DEVELOPMENT CENTER

EXTRA COPY

AF TECHNICAL REPORT NO. 6517, Part 3

DETERMINATION OF PHYSICAL PROPERTIES OF FERROUS AND NONFERROUS STRUCTURAL SHEET MATERIALS AT ELEVATED TEMPERATURES

D. E. Miller
Armour Research Foundation
Illinois Institute of Technology

December 1953

Materials Laboratory
Contract No. AF33(038)-8681
RDO No. R614-13

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Dayton, Ohio

Copy No.
51

FOREWORD

This report was prepared by the Armour Research Foundation under U. S. Air Force Contract No. AF33(038)-8681. The research and experimental investigation at the Armour Research Foundation was conducted as a project designated by ARF No. M012-6 for the Air Force. The contract was initiated under the research and development project identified by Research and Development Order No. R614-13, Development and Determination of Design Specification Data. It was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with K. D. Shimmin, 1/Lt., U.S.A.F., acting as Project Engineer.

In addition to Mr. D. E. Miller, author of the report, the following Foundation staff members contributed to the work covered by this Part: E. Chez, E. Frank, J. B. Hildebrand, G. Nagumo, W. T. Savage, and R. J. Wolf.

Respectfully submitted,

ARMOUR RESEARCH FOUNDATION OF
ILLINOIS INSTITUTE OF TECHNOLOGY

D. E. Miller

D. E. Miller, Associate Engineer

W. T. Savage

W. T. Savage, Supervisor
Materials Engineering Section

APPROVED:

S. J. Fraenkel

S. J. Fraenkel, Manager
Propulsion and Structural Research Department

DEM/edit/kf

ABSTRACT

In order to establish important design criteria, tensile, compressive, bearing, and shear properties have been determined for the following materials and conditions: (1) 14S-T6 aluminum alloy sheet (clad) at room temperature and at elevated temperatures ranging from 200° to 600°F, for exposure periods between 0.5 and 1000 hours; (2) 24S-T81 and 24S-T86 aluminum alloy sheet (clad) at room temperature and at 200°, 300°, and 400°F for exposure periods between 0.5 and 1000 hours; (3) FS1-H24 magnesium alloy sheet at 200°F, for exposure periods of 0.5 and 1000 hours; (4) 75S-T6 aluminum alloy sheet (clad) at 200°F, for exposure periods between 0.5 and 1000 hours; (5) cold rolled titanium and annealed titanium at 200°F, for exposure periods of 0.5 and 1000 hours; and (6) RC-130-A titanium alloy at room temperature and at temperatures ranging from 300° to 800°F, for exposure periods of 0.5, 100, and 1000 hours. A comparison was made between the tensile data and the data on other properties in an attempt to formulate a method for estimating all other elevated temperature properties from a knowledge of tensile elevated temperature properties and room temperature values of other properties. The conclusion was reached that the various properties are not related in a simple, consistent manner.

Test specimens, equipment, and procedures are described in detail. Test results are presented in the form of tables and curves to illustrate the effect of temperature and exposure time on the mechanical properties of the various materials under investigation.

PUBLICATION REVIEW

Manuscript copy of this report has been reviewed and found satisfactory for publication.

FOR THE COMMANDING GENERAL:

M. E. SORTE
Colonel, USAF
Chief, Materials Laboratory
Directorate of Research
WRIGHT AIR DEVELOPMENT CENTER

CONTENTS

CONTENTS (cont.)

ILLUSTRATIONS

ILLUSTRATIONS (cont.)

ILLUSTRATIONS (cont.)

ILLUSTRATIONS (cont.)

ILLUSTRATIONS (cont.)

ILLUSTRATIONS (cont.)

TABLES

TABLES (cont.)

DETERMINATION OF PHYSICAL PROPERTIES OF VARIOUS FERROUS AND NONFERROUS STRUCTURAL SHEET MATERIALS AT ELEVATED TEMPERATURES

I. INTRODUCTION

This program is a continuation of the investigation of the mechanical properties of various ferrous and nonferrous structural sheet materials at elevated temperatures which was begun by Armour Research Foundation (ARF) in November, 1949, under Exhibit A, Contract No. AF33(038)-8681. The purpose of the investigation was to obtain certain data needed for aircraft design. It was also desired to find a correlation between tensile properties and compressive, bearing, and shear characteristics at room and elevated temperatures, with a view toward establishing methods by which important physical properties can be predicted when little data are available.

Yield strength and ultimate strength data were considered to be of primary importance. Modulus values were also determined, but the test equipment lacked the refinement necessary for precise determination. Values of the tensile and compressive moduli of elasticity and compressive tangent modulus graphs are presented solely for the purpose of indicating trends. They should not be interpreted as exact values.

The present volume is the fourth report published since the beginning of the program. The previously published reports, descriptions of which appear in Appendix E, are: (1) AF Technical Report 6517, Part 1, "Determination of the Physical Properties of Nonferrous Structural Sheet Materials at Elevated Temperatures," December, 1951; (2) AF Technical Report 6517, Part 1, Supplement 1, "Determination of the Physical Properties of Ferrous and Nonferrous Structural Sheet Materials at Elevated Temperatures," March, 1952; and (3) AF Technical Report 6517, Part 2, "Determination of the Physical

Properties of Ferrous and Nonferrous Structural Sheet Materials at Elevated Temperatures," December, 1952.

The physical properties of structural materials are known to be influenced strongly by temperature. Generally speaking, temperature effects may be placed in two categories:

(1) Changes in properties which depend on temperature alone and are, in particular, independent of exposure time.

(2) Changes in properties which result from heat-induced structural alteration of the material and depend on the length of exposure as well as on the temperature.

If a material tends to soften progressively and becomes more ductile with continued exposure, it is said to anneal. If, on the other hand, its mechanical properties improve when it is exposed for a certain period of time, the material is said to precipitation-harden or age-harden. Time effects and temperature effects were the primary factors investigated in the sheet materials testing program.

II. OBJECTIVES AND SCOPE OF INVESTIGATION

The specific objectives of the phase of the program covered by this report were:

(1) To determine the compressive, bearing, and shear properties of four aluminum alloys, one magnesium alloy, and three titanium alloys at room and elevated temperatures, for various exposure periods.

(2) To correlate, if possible, the above-named properties with tensile properties determined under corresponding temperature and exposure conditions.

The temperature and exposure conditions under which tests were conducted are indicated in Table 1 for the various materials.

Table 1

SCHEDULE OF TEMPERATURES AND EXPOSURE TIMES

Material	Temperatures, °F	Exposure Times, hr
Clad 14S-T6 Aluminum	75, 200, 300, 400, 500, 600	1/2, 2, 10, 100, 1000
Clad 24S-T81 Aluminum	75, 200, 300, 400	1/2, 2, 10, 100, 1000
Clad 24S-T86 Aluminum	75, 200, 300, 400	1/2, 2, 10, 100, 1000
Clad 75S-T6 Aluminum	200	1/2, 2, 10, 100, 1000
FS1-H24 Magnesium	200	1/2, 1000
Annealed Titanium	200	1/2, 100
Cold Rolled Titanium	200	1/2, 100
RC-130-A Titanium	200, 300, 500, 600, 800, 1000	1/2, 100, 1000

At each of the conditions listed in the table, the following mechanical properties were determined:

1. Compressive Yield Stress (0.2% offset)
2. Modulus of Elasticity in Compression
3. Tangent Modulus (Compression)
4. Bearing Yield Stress (2% offset)
5. Ultimate Bearing Stress
6. Ultimate Shear Stress
7. Tensile Yield Stress (0.2% offset)
8. Ultimate Tensile Stress
9. Modulus of Elasticity in Tension

III. MATERIAL SPECIFICATIONS

Materials for the elevated temperature testing program were either ordered to specifications by ARF or furnished directly by the sponsor. Compressive, bearing, and tensile tests were performed with sheet specimens of 0.064 inch nominal thickness, while the shear test and its associated tensile test were conducted with specimens machined from 3/16 inch nominal size sheet. Data on the compositions and room temperature properties of each material are summarized in succeeding paragraphs.

A. 14S-T6 Aluminum Alloy (Clad)

The 14S-T6 clad aluminum sheet material was procured by ARF to Federal Specification No. QQ-A-255 from an Alcoa distributor. It was furnished in the heat-treated condition. The T6 designation indicates that the temper of this material was produced by solution heat treatment followed by artificial aging. Tests performed at ARF indicate that 14S-T6 aluminum alloy has the properties and composition listed below:

Nominal Chemical Composition

	Per Cent
Copper	4.4
Silicon	0.8
Manganese	0.75
Magnesium	0.35
Aluminum	Balance

Mechanical Properties of 0.064-inch Sheet

Tensile Strength, psi	63,200
Yield Strength, psi	57,200
Modulus of Elasticity, psi	10.6×10^6

B. 24S-T81 and 24S-T86 Aluminum Alloys (Clad)

The 24S-T81 and 24S-T86 aluminum alloy sheets, which were procured by ARF from an Alcoa distributor, complied with Federal Specification No. QQ-A-362A and Air Force-Navy-Aeronautical (ANA) Specification No. AN-A-42. Both sheets were heat-treated by the producer. The T81 and T86 designations indicate that these materials had undergone the basic T8 process, which involves solution heat treatment, then cold work, and finally artificial aging. By varying the amount of cold work, or the aging conditions, different tempers may be produced. In this case, the digits 1 and 6 describe the final tempers which result from cold working the material 1% and 6%, respectively. The 1% cold work is obtained in a routine flattening operation which follows solution heat treatment. Actually, T81 is artificially aged T3, and T86 is artificially aged T36. The following is the nominal composition of 24S Aluminum:

Nominal Chemical Composition

	Per Cent
Copper	4.5
Manganese	0.6
Magnesium	1.5
Aluminum	Balance

The mechanical properties resulting from the T81 and T86 treatments are tabulated below, as determined in room-temperature tests at ARF.

Mechanical Properties of 0.064-inch Sheets

	24S-T81	24S-T86
Tensile Strength, psi	65,600	72,700
Yield Strength, psi	61,900	69,100
Modulus of Elasticity, psi	10.2×10^6	11.2×10^6

C. 75S-T6 Aluminum Alloy (Clad)

The requirements for 75S-T6 aluminum sheet are given in ANA Specification No. AN-A-10. This material was tested in the first supplement of the program under a different set of conditions. To insure correlativity of data, the 75S-T6 sheet tested in the current phase was drawn from the same lot as the material previously used. Like the other aluminum materials, it was furnished in the heat-treated condition (in this case T6, which indicates solution heat treatment and artificial aging) by the Alcoa distributor, who issued the following data concerning its properties:

Nominal Chemical Composition

	Per Cent
Zinc	5.1
Magnesium	2.1
Copper	1.2
Others	1.9
Aluminum	Balance

Mechanical Properties of 0.064-inch and 3/16-inch Sheets

Tensile Strength, psi	76,000
Yield Strength, psi	67,000
Modulus of Elasticity, psi	10.4×10^6

D. FS1-H24 Magnesium Alloy

The FS1-H24 magnesium sheet was produced by Dow Chemical Company under compliance with Federal Specification No. QQ-M-54. This material was tested under a different set of conditions in a previous phase of the program. At that time, it was designated FS-1H; nothing has been changed except the designation, however. Sheet drawn from the same lot was used in the current phase. The properties of this material, as published by the producer, are listed below:

Nominal Chemical Composition

	Per Cent
Aluminum	2.5 to 3.5
Manganese	0.2
Zinc	0.7 to 1.3
Silicon	0.3
Others	0.3
Magnesium	Balance

Mechanical Properties

	0.064-inch Sheet	1/4-inch Sheet
Tensile Strength, psi	41,700	40,500
Yield Strength, psi	31,600	31,600
Elongation, per cent	12.5	12.5

E. Annealed Titanium

Annealed titanium sheet was tested in an earlier phase of the program under different temperature conditions. Specimens tested in the present phase were made of material drawn from the same lot as the sheet used previously. The annealed titanium sheet was purchased from Allegheny Ludlum Steel Company through Titanium Metals Corporation. Designated Ti50 by its producer, this material complies with the specifications given in "Purchase Requirements for Titanium Sheet," published by the Materials Laboratory, Wright-Patterson Air Force Base, on November 10, 1949. Annealed titanium is commercially pure metal (not more than 0.1% carbon) heat-treated to a condition under which maximum elongation may be obtained.

F. Cold Rolled Titanium

As was the case with annealed titanium, cold-rolled titanium sheet was tested under different temperature conditions in a previous phase of the program. Again, the material for the present phase was drawn from the same lot as the sheet used earlier. Cold rolled titanium is chemically the

same as annealed titanium, i.e., it is commercially pure metal. The specifications for this material, which are given in "Purchase Requirements for Titanium Sheet," further state that the titanium "shall be cold rolled the amount necessary to give the maximum tensile strength which can be reached while retaining sufficient ductility to undergo 90-degree cold-bend tests both parallel and perpendicular to the direction of rolling over a diameter not greater than 5 times the sheet thickness with an approximate elongation of 10% in 2 inches parallel to the direction of rolling." At the time of the previous tests, the elongation of the cold rolled titanium varied between 7.5% and 12%. The material complied with the bend test requirement when bent parallel to the direction of rolling. However, it failed at 80 degrees when bent in the direction perpendicular to the rolling direction.

The cold-rolled titanium sheet was procured from Allegheny Ludlum Steel Corporation through Titanium Metals Corporation. The producer has assigned the designation Ti75a to commercially pure titanium which complies with the specifications described above.

G. RC-130-A Titanium Alloy

RC-130-A titanium alloy is a sheet material developed by Rem-Cru Titanium, Incorporated, for aircraft use. In the bulletin, "Rem-Cru Titanium and Titanium Alloys," reprinted by that concern in April, 1951, this material is described as "essentially a binary 7% manganese, titanium-base alloy." The bulletin includes a tabulation of mechanical properties based on limited testing, and hence subject to revision. These properties are listed below. According to the manufacturer, the material exhibits optimum mechanical properties in the as-furnished state. Higher strength can be obtained through heat treatment, but ductility will be reduced disproportionately.

The RC-130-A sheet material tested in the present phase of the program was furnished by the sponsor.

Mechanical Properties

	Longitudinal	Transverse
Tensile Strength, psi	150,000	153,000
0.2% Offset Tensile Yield Strength, psi	140,000	150,000
Tensile Elongation 2-in. Gage Length, %	15	12
Reduction of Area, %	32	32
Proportional Limit, Tension, psi	105,000	130,000
Modulus of Elasticity, psi	15.5×10^6	15.5×10^6

IV. PREPARATION OF TEST SPECIMENS AND PRELIMINARY AGING

Specimens for compressive, bearing, and tensile tests were prepared from sheets of 0.064-inch nominal thickness. Shear test specimens and specimens for the associated tensile test were machined from 3/16-inch sheets, except in the case of the FS1-H24 magnesium alloy, for which 1/4-inch plate was used. To insure that the tests would give minimum values of sheet properties, blanks of all materials except RC-130-A titanium alloy were band-sawed in such a way that specimens would be stressed in the direction perpendicular to the direction of rolling when the load was applied. RC-130-A is weakest in the longitudinal direction. All test blanks were machined to final dimensions before aging.

Ovens equipped with automatic temperature controls were used for aging at temperatures of 200°, 300°, 400°, and 500°F. Specimens were placed flat on a single shelf to minimize warping and to provide a like environment for all specimens with respect to surface conditions as well as temperature. Checks made at various times during the aging cycle indicated that the temperatures of specimens did not differ by more than ±2°F from the mean of the temperatures of all specimens in the oven.

A heat treating furnace was used for aging specimens at 600°, 800°, 1000°, and 1200°F. Furnace temperature was controlled by a thermocouple inserted in a dummy test blank. To minimize aging variations, specimens were placed flat on the same metal rack and distributed symmetrically about the dummy control blank.

The following sections contain descriptions of the specimens used in the four types of tests conducted in the elevated temperature materials testing program.

A. Tensile Specimens (See Fig. 1)

Sheet tensile specimens were prepared in compliance with the requirements stipulated in AF Technical Report 6517, Part 1 (December, 1951), which was concerned with work done during the first year of the program.

As mentioned previously, the initial step in the preparation of all specimens is the sawing of test blanks from sheet stock. After sawing, the tensile test blanks were machined to the final dimensions indicated in Fig. 1 by milling operations. Burrs were then removed from the specimens with No. 00 emery paper. Tensile specimens made from 3/16-inch stock were machined to a width of 0.400 inch, instead of 0.500 inch, to avoid overstressing the grips.

B. Compressive Specimens

Compressive test blanks were prepared in accordance with the description given in Reference 1. The final dimensions of compressive specimens are indicated in Fig. 1. Upon completion of milling operations, burrs were removed with emery paper.

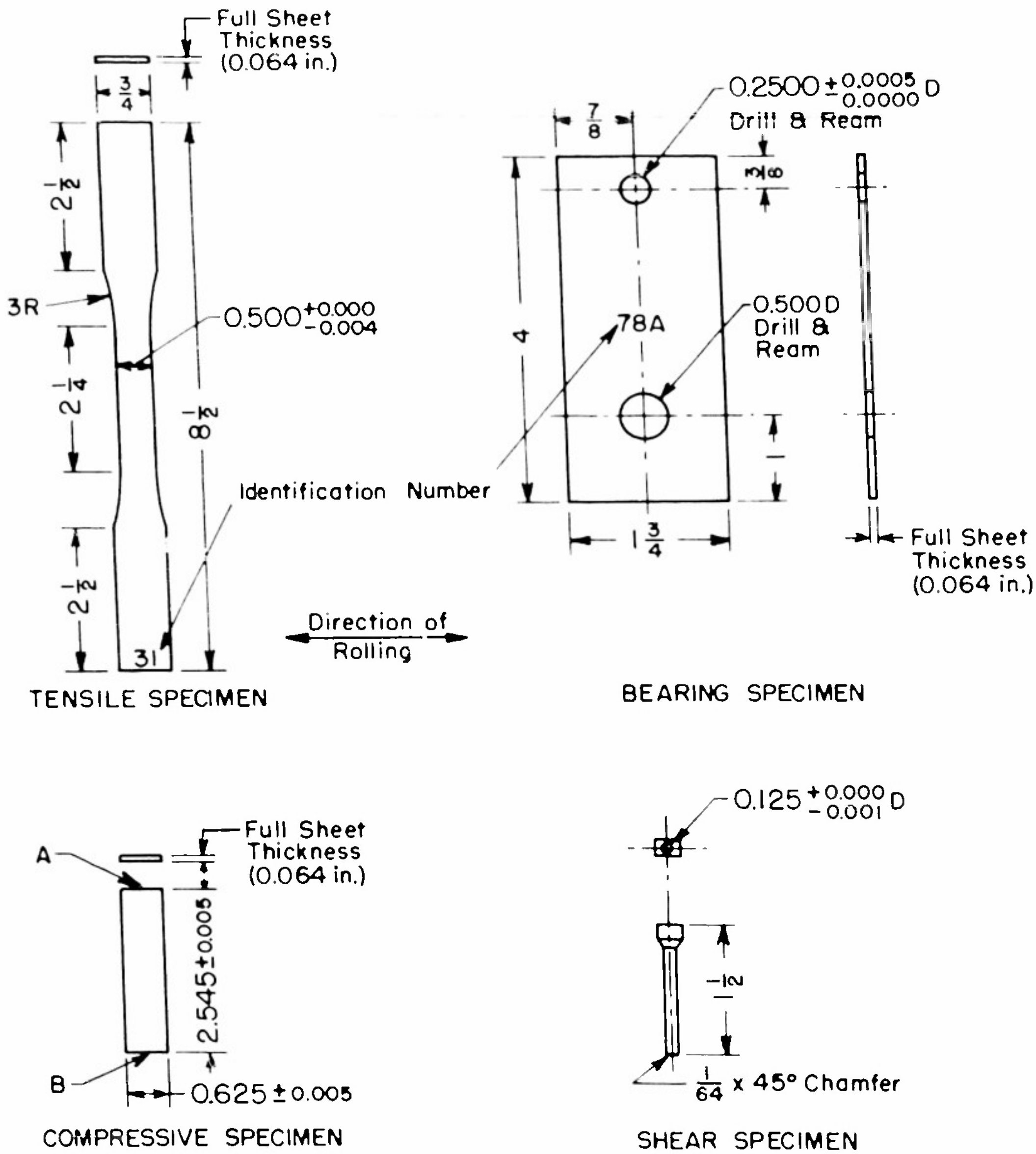

Fig. 1 TEST SPECIMENS

C. Bearing Test Specimens

Bearing test specimens were machined to the dimensions indicated in Fig. 1. In sawing the test blanks care was taken to insure that the center line passing through the two reamed holes was perpendicular to the direction of rolling. Burrs were removed from the edges of the reamed holes with emery paper after machining.

D. Shear Test Specimens

The shear test blanks were saw-cut from 3/16 and 1/4-inch sheet in such a way that after machining the axis of the specimen was perpendicular to the direction in which the sheet was rolled. Specimens were machined from the test blanks by turning them on centers in a lathe to the dimensions shown in Fig. 1.

V. TEST EQUIPMENT

The apparatus needed to conduct an elevated temperature mechanical properties test consists of three component systems:

1. A loading system comprised of a test machine and fixtures.

2. A measuring system consisting of a deformometer for reproducing displacements and an indicator or gage for measuring them.

3. A heating system composed of a furnace and its control auxiliaries.

Since the various tests differ in nature, special fixtures, furnaces, and instruments are required to perform them. Descriptions of this special equipment, which was constructed during the initial phase of the program, are presented in the sections below.

Compressive, bearing, and shear tests were conducted on a 120,000-pound Riehle Universal hydraulic testing machine. Satisfactory loading accuracy was obtained by employing the 6000-pound range scale.

A 20,000-pound Olsen Universal hydromechanical testing machine was used for tensile tests. It was found convenient to use the 10,000-pound range scale for all materials tested during the present phase of the program.

A. <u>Tensile Test Apparatus</u> (See Fig. 2)

The tensile loading fixture consists of a pair of Riehle tensile grips and two adjustable rods for connecting the grips to self-aligning pins at the heads of the testing machine. The grips were designed especially to hold flat specimens, and have wedge-shaped jaws with serrated faces for this purpose. Continued testing at high temperatures in this and in previous phases of the program caused the serrations to temper and become dull. To prevent slipping of the specimen in the grips, it was necessary to drill a small hole in each end of the specimen and pass pins through these holes after the specimen had been mounted in the grips. When the load was applied, the pins tightened the grips against the specimen, thus preventing slippage.

The tensile test extensometer is comprised of a pair of rigid yokes shaped like wide two-tined forks. At their midpoints, the yokes are connected by an eye bolt assembly, which permits the lower yoke to pivot with respect to the upper. The extensometer is mounted on the specimen by means of screws with conical points located at the ends of the tines of the yokes. Gage points were marked on the edges of the specimen to facilitate mounting. A tube projecting upward out of the furnace is fastened to the opposite, or fork-handle, end of the upper yoke. A rod concentric with this tube, and having a rounded end, extends down to the fork-handle end of the lower yoke, contacting it on a shallow indentation of spherical contour. Since the "handles" and "tines" of the yokes are of equal length, measured from the pivot, the displacement of the rod with respect to the tube is equal

A11144

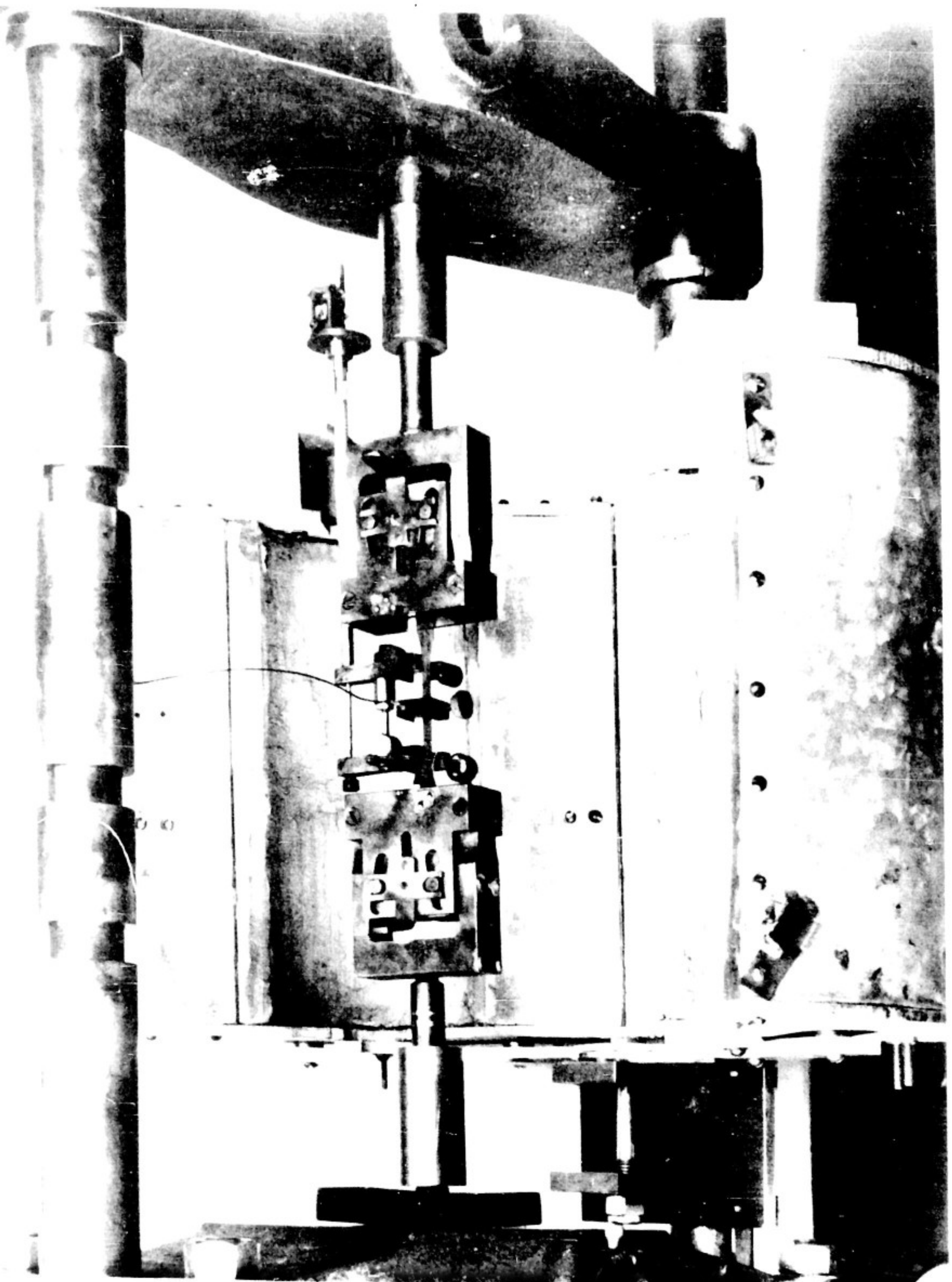

Fig. 2 TENSILE TEST APPARATUS SHOWING EXTENSOMETER, CONTROL THERMOCOUPLE, AND FURNACE

to the displacement of one set of contact points relative to the other set. This displacement is measured by a Tuckerman optical strain gage mounted on the upper end of the tube, above the furnace. The lozenge of the Tuckerman gage contacts an adjustable collar on the rod; lozenge rotation is therefore actuated by motion of the rod. The adjustable collar is retained on one end by a compressive spring and on the other end by a thumb nut. The gage can be reset as often as required by merely turning the thumb nut.

The furnace in which tensile specimens were tested is cylindrical in form. Its test chamber, also cylindrical, measures 12 inches in length by 5 inches in diameter. Heat is produced by four semicylindrical resistance-type electric heaters, each 6 inches long and rated at 850 watts on a 115-volt supply. The furnace was constructed in semicylindrical halves hinged together along a generating line of its exterior surface. Owing to this construction, the test chamber is readily accessible for the insertion and removal of specimens. Each half is made up of two heaters placed end to end. The heaters are backed by insulation 3 inches thick and encased in a sheet steel shell. The ends of the furnace, which are made of transite plate, cover the top and bottom of the test chamber, thus restricting convective air flow. Small openings are provided to accommodate the extensometer tube and the loading pins.

The heaters were made individually controllable by wiring them in parallel and employing a Variac in each of the four branches of the circuit. With this arrangement, it was possible to regulate the distribution of temperatures in the furnace. A Micromax controller, actuated by the signal from a chromel-alumel thermocouple, was used to obtain the desired furnace temperature. The control thermocouple was mounted at the center of the specimen and held in contact with it by a small C-clamp of special design.

B. Compressive Test Apparatus

The design of the compressive test fixture used in the current program was based on the fixture developed by Dorn and described in Reference 1. Basically, this fixture consists of a base with a bearing plate of hard, temperature-resisting material, two steel guide blocks, and a guided loading plunger. The bearing plate is the stationary loading surface. The guide blocks align the sheet specimen and prevent lateral buckling. Figure 3 shows the compressive test fixture and compressometer assembled for use.

In design, the compressometer is essentially the same as the extensometer discussed in the previous section. However, the instruments differ in two respects: namely, pivot arrangement and rod mounting. The extensometer has an eye bolt pivot device, while in the compressometer an elastic hinge-type pivot is used. As a result of this elastic hinge construction, the compressometer averages the relative displacements between upper and lower gage points on opposite edges of the specimen. The rod of the extensometer contacts the lower yoke by point bearing; in the compressometer, however, the rod is attached to the lower yoke by an elastic hinge. A more secure rod mounting is required in the compressometer because during displacement the yoke pulls the rod downward through the tube. In the extensometer, the rod is pushed upward.

Heat is supplied to the test fixture and specimens by four cartridge heaters inserted into holes drilled longitudinally in the guide blocks, and by a flat plate heating element in the base of the fixture. To reduce heat losses, the entire assembly is placed in a closed, insulated container during tests. Transite cover plates with openings for the extensometer tube and test machine loading ram were used to eliminate convective air currents.

A11145

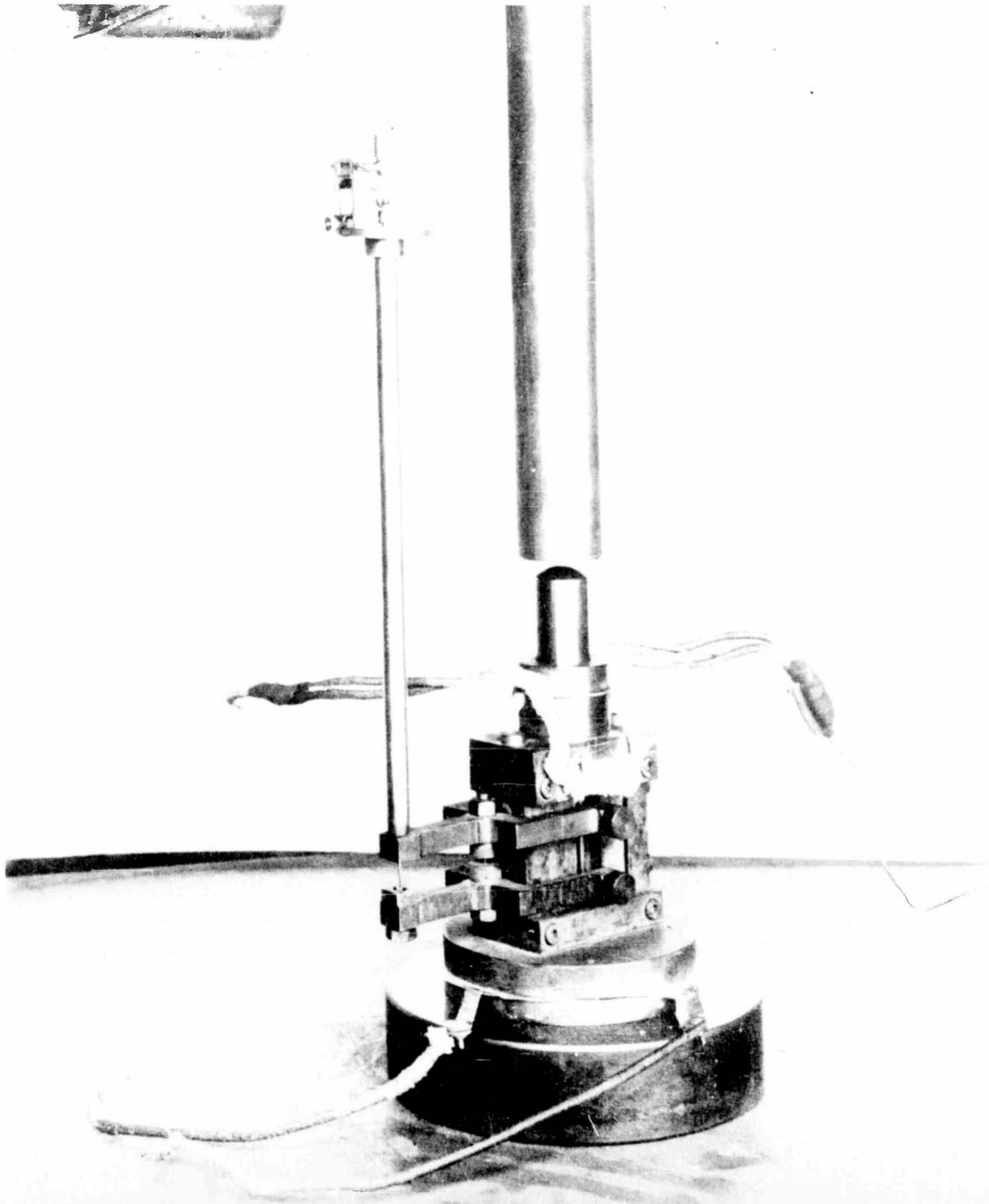

Fig. 3 COMPRESSIVE TEST FIXTURE WITH COMPRESSOMETER MOUNTED ON A TEST SPECIMEN

The control thermocouple was located in a small hole drilled close to the specimen contacting surface of one of the guide blocks.

C. Bearing Test Apparatus

The bearing test fixture was constructed in accordance with the specifications given in Reference 2. Figure 4 shows the fixture, specimen, deformometer, and furnace assembled for testing.

The test fixture is essentially a pair of double shear jigs constructed from hardened and ground steel plates. A 0.250-inch hardened high speed steel pin inserted through a drilled and reamed hole in the upper jig loads the rivet hole of the specimen. The specimen is retained at the lower jig by a 0.500-inch pin.

In a bearing test, it is desired to measure the deformation of a rivet hole with respect to the metal in the vicinity of the hole. A precise measurement is difficult to make because deformations occur over the entire active length of the specimen when the load is applied. Fortunately, however, design information is based on bearing deformations which stress the material well into its plastic range. Since plastic deformations are highly localized in this test, errors which arise as a result of unrecorded elastic translations of the hole become insignificant.

The deformometer designed for use in the current program measures the displacement of the hardened steel pin relative to points on the edges of the specimen in line with the edge of the rivet hole. It consists of two parts: (1) a reference clamp which is fastened to the specimen by means of hardened screws with conical tips; and (2) a framework for holding the dial gages which measure the deformation. From Fig. 4, the fashion in which the reference clamp mounts on the specimen can be observed. The clamp has a thin central section which fits between the plates of the upper jig. Two

A11143

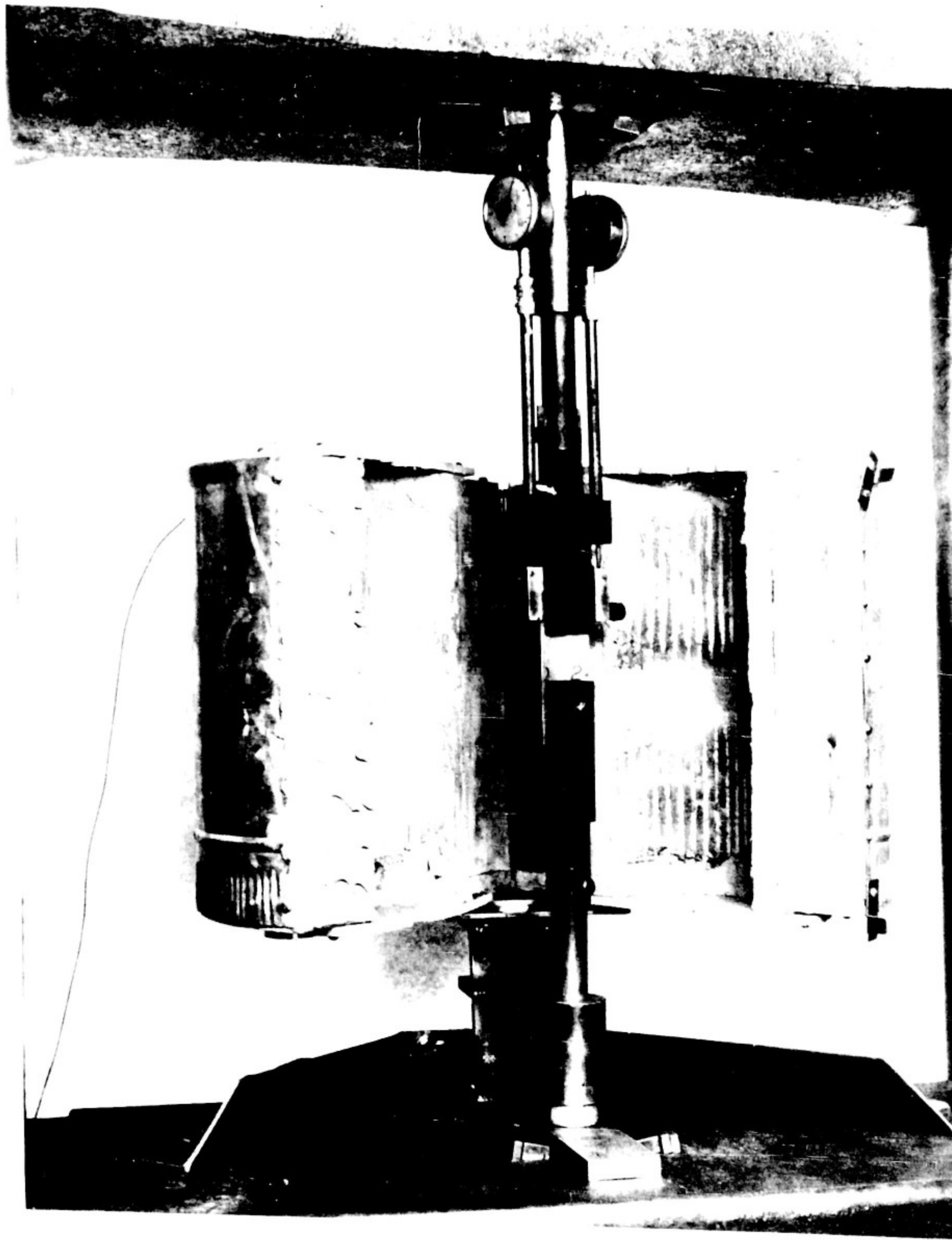

Fig. 4 BEARING TEST APPARATUS

tubes supporting dial gages above the furnace are fastened on the upper jig, one tube over each end of the test clamp. Rods with rounded ends pass through these tubes and are held against ends of the clamp by dial gage spring pressure. It should be noted that the quantity actually measured by each dial gage is the displacement of the upper jig with respect to one end of the test clamp. The validity of this measurement is based on the fact that elastic deformations of the 0.250-inch steel loading pin, of the upper jig, and of areas of the specimen between the gage points and the rivet hole, are negligible compared to the deformation of the hole. In data tabulations, the deformation is computed by averaging the two dial gage readings.

The specimen and fixture were heated to the desired test temperature in a furnace of the same design as that used in tensile tests. The control thermocouple was inserted in a small hole drilled through one of the plates of the upper jig near the loading pin hole.

D. Shear Test Fixture

The fixture used for performing shear tests is a tensile loading double shear jig constructed in accordance with the specifications given in Fig. SM-17T of Reference 3. Figure 5 shows the shear fixture with a specimen in place. The upper half of the fixture consists of two hardened and ground steel side plates separated by a spacer plate 0.126 inch thick. The lower half of the fixture, which is the shear tool, was made from a hardened steel plate ground to a thickness of 0.125 inch. To insure proper alignment, the 0.125-inch shear specimen holes in the upper half of the fixture were reamed after the part was assembled. The upper and lower fixture elements were both attached to the testing machine heads with pin connections to facilitate fixture alignment and specimen insertion.

A11276

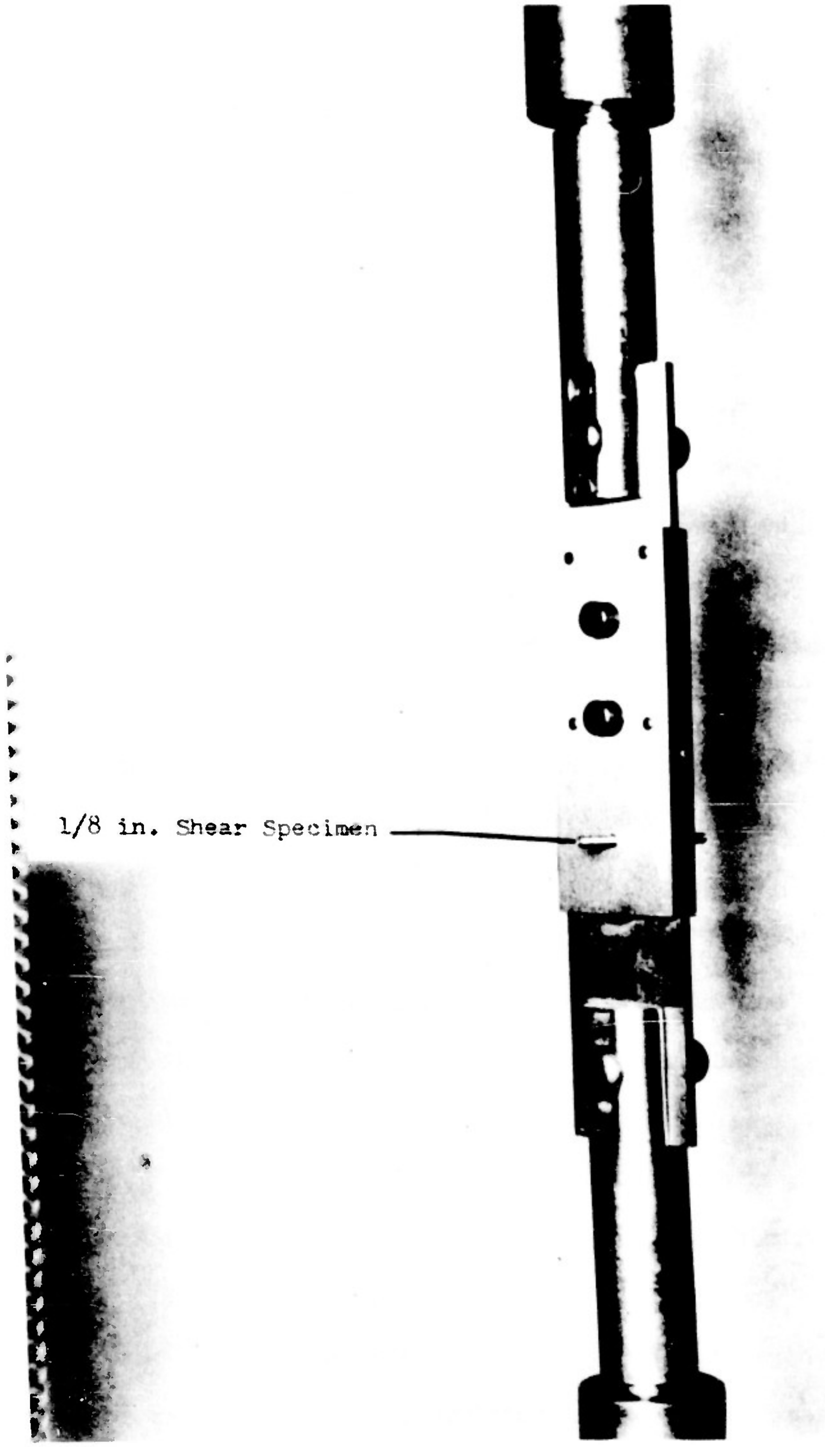

Fig. 5 SHEAR TEST FIXTURE

Since only the ultimate shear stresses were determined by these tests, no deformometers were employed. The same furnace used in the bearing test was used for heating shear specimens. Temperatures were controlled by a thermocouple inserted in a small hole in the upper fixture close to the specimen.

VI. TEST PROCEDURE

Before test work at elevated temperatures was begun, surveys were made of the temperature distributions in dummy specimens at various nominal test temperatures. These check runs were made in order to (1) correlate the temperatures recorded by the control thermocouple and by the thermocouples located in the test specimen, (2) determine the temperatures at various locations on the test specimen, and (3) determine the Variac settings required to maintain each test temperature. Figures showing the locations of the control thermocouples and tabulations of the results of the temperature surveys, as reproduced from the final report for the initial phase of the program, are presented in Appendix A.

A. Tensile Test

The first step in the tensile test is final specimen preparation. This includes recording the width and thickness of each specimen, as determined by micrometer measurement, and marking the 2-inch gage length on the specimens with a fixture made especially for this purpose. Next, the extensometer is placed on the specimen by tightening the four conically-pointed thumb screws in the gage marks. The specimen, with extensometer attached, is then mounted in the test machine, following which the thermocouple is set in place. Lastly, the test chamber is closed around the assembly, so that only the loading pins and extensometer tube protrude from the furnace.

The test is not begun until the furnace has been at test temperature for 15 minutes. During the test, the load is increased progressively to produce a strain rate of about 0.01 inch per inch per minute. Deformations are observed and recorded at predetermined load intervals by reading the Tuckerman gage with an Autocollimator. When it becomes clear from the gage readings that the yield point has been surpassed, the extensometer is removed from the specimen. The test is then continued until the specimen fractures.

Three properties, namely tensile yield strength, ultimate tensile strength, and modulus of elasticity, are determined from the recorded data. Stress-strain diagrams are plotted to determine the yield strength and the modulus of elasticity. The value of the latter property is found by computing the slope of the straight line portion of the curve. For materials which do not exhibit a definite yield point, the 0.2% offset definition of yield strength is used. So defined, the yield strength is the stress at which the strain deviates by 0.002 inch per inch from the linear law $\epsilon = \sigma/E$. Ultimate strength is computed from the highest load recorded during the test.

B. Compressive Test

The compressive test preliminaries include measuring the width and thickness of the specimen, marking the 1-inch gage length on its edges with a special tool, polishing its surfaces with No. 00 eméry paper, and coating it with Molykote dry lubricant to reduce friction between the specimen and the guide blocks. After these procedures have been completed, the specimen is placed in the test fixture. Firm, but not binding, support is achieved by turning the adjusting screws of the movable guide block until they are

finger-tight. The extensometer is then attached to the specimen by locating the thumb screws in the gage marks. Finally, the entire assembly is placed in a closed, insulated container to eliminate convective air flow during the heating period.

To allow equalization and stabilization of temperatures within the furnace, loading is not commenced until the specimen has been at test temperature for 15 minutes. During the test, loads are increased progressively to maintain a strain rate of approximately 0.01 inch per inch per minute. Deformations are observed through the Tuckerman Autocollimator and recorded at specified load intervals. The test is terminated when it appears certain from the recorded deformation data that the yield point of the material has been exceeded.

Two properties, compressive yield strength and compressive modulus of elasticity, are determined from the test data. The modulus of elasticity is given by the slope of the linear portion of the stress-strain diagram. However, at high temperatures, the stress-strain relationship is often non-linear throughout. In such cases, the modulus of elasticity is taken to be the slope of the tangent to the curve at or near the origin. Compressive yield strength is calculated in accordance with the 0.2% offset definition.

After all compressive tests of a particular material have been completed, the stress-strain curves are reviewed and a typical curve is selected for each temperature and exposure condition. These curves are then used to construct tangent modulus diagrams.

C. <u>Bearing Test</u>

Before the bearing test is begun, the thickness of the specimen is measured at several places in the vicinity of the rivet hole with a micrometer, and the average thickness is recorded. Then gage points are

punch-marked on the edges of the specimen in line with the edge of the rivet hole nearest its end. Next, the deformometer clamp is attached to the specimen by tightening the conically-tipped screws into the gage marks. The specimen is then placed in the upper jig of the test fixture and retained by the 0.250-inch hardened steel pin. Finally, the lower fixture is set in place, the furnace is closed, and the specimen is heated to test temperature.

After the temperature has stabilized, a light load is applied to bring the specimen and deformometer into final alignment. The dial gages are set to zero at this time. During the test, the load is regulated to produce a strain rate of approximately 0.01 inch per inch per minute. Dial gage readings are recorded until the rivet hole has been deformed beyond the yield point. Deformation readings are then discontinued and the load is increased rapidly until failure of the specimen occurs.

Two properties, bearing yield strength and ultimate bearing strength, are determined from this test. In a bearing stress calculation, the load is divided by the projected area of the rivet hole, i.e., by the product of hole diameter and specimen thickness. The bearing yield strength is defined as the bearing stress at which the inelastic deformation of the rivet hole is equal to 2% of the original hole diameter. Therefore, to find the yield strength, it is necessary to construct a stress-deformation or load-deformation diagram. Ultimate bearing strength is computed from the maximum load recorded during the test.

D. <u>Shear Test</u>

Before the shear specimen is inserted in double shear jig, its diameter is measured with a micrometer and recorded. The furnace is closed around the fixture and specimen, which are then heated until a state of

thermal equilibrium prevails. The load is applied at a rate which produces failure of the specimen in approximately 3 minutes. Since this test is intended to furnish data on ultimate shear strength only, no deformations are measured. The ultimate shear strength is calculated by dividing the maximum observed load by 2 times the area of the cross section of the specimen.

VII. EXPERIMENTAL RESULTS

In Appendix B, the results of individual tests and the average values for each temperature and exposure condition are presented in tabular form. It will be noted that room temperature data is included in these tables; exposure period designations do not apply to room temperature results, of course. The pages on which results for a particular material appear can be found by consulting the list of tables at the beginning of the report.

Test data are also shown graphically in Figs. 6 through 32 and in Appendices C and D. The various types of curves drawn to illustrate test results are discussed in the sections which follow.

A. Stress Versus Exposure Time Curves

As was mentioned earlier in the report, the primary intention of the program was to assess the influence of two factors, temperature and exposure time, on various mechanical properties. More specifically, it was desired to determine the manner in which mechanical properties vary as a function of time at a given temperature. Information of this kind on any one property can be obtained by plotting, for each temperature, a curve with the mechanical property as ordinate and exposure time as abscissa. The fashion in which temperature affects the property can then be observed by drawing all such curves on one diagram.

From the average values obtained at each temperature and exposure condition, diagrams of this nature have been constructed for the yield tensile, compressive, and bearing strengths, and the ultimate tensile, bearing, and shear strengths of all materials tested. It was found convenient to use semilogarithmic graph paper for these curves, because the spacing of test exposure intervals is more uniform on a logarithmic scale than on a linear scale. The stress versus exposure time diagrams are listed in the Table of Illustrations at the beginning of the report.

B. Modulus of Elasticity Versus Temperature Curves

In previous phases of the program, it was observed that tensile and compressive moduli of elasticity did not vary in consistent fashion as a function of exposure time at most temperatures. The same behavior was observed in the present phase of the program. Therefore, curves illustrating the variation of these properties with increasing time of exposure were not constructed. Instead the average values of the moduli for all exposure times at each temperature were calculated and this data was used to construct modulus of elasticity versus temperature diagrams. In interpreting these curves it is important to remember that the plotted values represent averages; the tabulated data on moduli of elasticity should be reviewed before conclusions are drawn.

C. Stress-Strain and Stress-Deformation Curves

For each temperature and exposure condition, typical tensile and compressive stress-strain curves were selected for presentation in the report. All tensile, or compressive, curves from tests conducted at a common temperature are drawn side by side on the same diagram to facilitate observation of the effect of exposure time. In the same fashion, typical curves

are presented illustrating the stress-deformation relationship of the bearing test. Yield strengths are indicated by points of intersection between the curves and line segments drawn parallel to their linear portions.

The stress-strain and stress-deformation curves, which are listed in the Table of Illustrations, appear in Appendix C.

D. Compressive Tangent Modulus Curves

Tangent modulus data, which is important in stability calculations, was obtained from typical compressive stress-strain curves for each temperature and exposure condition. Tangents were constructed at several points along each curve beyond its proportional limit, and the slopes of the tangents were calculated. Usually, five points were sufficient to obtain satisfactory data. The values so obtained were then plotted as function of exposure time at each temperature. Again, to facilitate analysis of the effect of temperature, all curves for a given material were drawn on the same diagram. The tangent modulus curves are presented in Appendix D.

VIII. SUMMARY OF TEST RESULTS

As stated earlier, the effects of temperature on the mechanical properties of structural materials may be placed in two classes: (1) changes caused by temperature alone, and (2) changes which result from structural alteration of the material and which, therefore, depend on time as well as on temperature.

When a material has been exposed for 1/2 hour, changes in its mechanical properties may be attributed to the influence of temperature alone, provided the exposure temperature is well below the transformation temperature of the material. However, if the material has been exposed for a longer interval, the effect of exposure time must also be considered. In analyzing the experimental data, it has been assumed that the results of tests performed

after 1/2 hour exposure indicate the mechanical properties of structurally unaltered material at the test temperature. Data from tests conducted after longer exposure are considered to show the influence of structural alteration.

The test results for each material are discussed separately in the sections which follow.

A. Effect of Temperature and Exposure Time on 14S-T6 Aluminum Alloy (Clad)

In Table 2, the average values of the mechanical properties of 14S-T6 aluminum alloy sheet material for various temperature and exposure conditions are expressed as percentages of the room temperature values. Curves showing the manner in which tensile, compressive, and bearing yield strengths, and tensile, bearing, and shear ultimate strengths vary with exposure time are presented in Figs. 6 to 8.

It can be seen that all yield strengths exhibit the same general behavior; this is true also of the ultimate strengths of 0.064-inch material. Certain characteristics of the graphical and the tabulated data merit additional notice, however.

Observe that the material is slightly weaker at 200°F than at room temperature. The diminution of strength appears to be wholly attributable to the influence of temperature, because the curve is almost horizontal throughout its length. As a matter of fact, all values for the 1000-hour exposure period are higher than the 1/2-hour values. Although the differences are slight, the consistency of this phenomenon suggests that lengthy exposure at 200°F increases the properties of this material somewhat. Apparently, prolonged heating at this temperature supplements the artificial aging process to which the material is subjected during the T6 treatment.

Table 2

MECHANICAL PROPERTIES OF 14S-T6 ALUMINUM ALLOY SHEET FOR VARIOUS TEMPERATURES AND EXPOSURE CONDITIONS EXPRESSED AS A PERCENTAGE OF ROOM TEMPERATURE VALUES

Temp °F	Exposure Time, hr	Yield Strength Tensile	Yield Strength Compressive	Yield Strength Bearing	Ultimate Strength Tensile	Ultimate Strength Bearing	Modulus of Elasticity Tensile	Modulus of Elasticity Compressive	Ultimate Strength, 3/16 in. Tensile	Ultimate Strength, 3/16 in. Shear
78		57,300 psi	69,000 psi	93,600 psi	63,200 psi	113,000 psi	10.6×10^6 psi	10.6×10^6 psi	68,800 psi	42,300 psi
200	0.5	94.6	89.0	94.2	93.7	93.5	97.1	101.0	97.0	98.5
	2	93.5	89.5	94.7	93.9	93.4	99.0	98.1	97.0	95.1
	10	93.5	91.3	93.7	93.7	93.8	95.3	94.3	97.4	96.6
	100	97.3	89.9	95.0	97.8	93.8	96.2	96.2	97.0	96.3
	1000	101.6	90.0	97.2	98.5	95.0	99.0	90.6	98.9	96.6
300	0.5	87.3	82.5	86.5	88.0	84.3	101.8	102.8	93.5	89.0
	2	86.8	79.1	87.3	86.6	84.0	86.8	86.8	93.0	86.5
	10	83.8	75.4	85.7	85.8	84.5	90.6	92.5	93.0	88.2
	100	85.6	76.1	83.0	85.2	80.1	99.0	90.6	91.5	81.6
	1000	74.4	70.2	74.8	75.6	74.3	91.5	95.3	83.3	75.2
400	0.5	65.8	66.8	70.2	71.3	68.3	96.2	100.0	88.7	72.1
	2	66.0	60.0	63.0	65.7	60.5	99.0	94.3	85.7	64.5
	10	45.7	40.7	43.8	46.2	43.1	98.1	88.6	59.6	48.5
	100	33.2	29.4	34.0	34.6	34.0	93.4	89.6	48.0	35.7
	1000	27.1	23.4	27.4	26.6	29.4	94.3	91.5	41.1	31.0
500	0.5	26.8	31.8	32.9	25.2	33.4	72.6	85.8	70.2	37.6
	2	b	25.0	24.1	b	24.8	75.5	93.4	46.0	26.5
	10	19.7	17.8	18.15	19.0	17.8	71.7	93.4	36.4	20.8
	100	17.8	15.4	15.9	17.4	16.0	85.8	67.0	33.4	13.7
	1000	15.9	13.8	14.85	18.2	16.0	77.3	66.0	39.0	19.4
600	0.5	18.0	15.4	20.2	17.7	20.4	79.2	65.0	62.4	21.3
	2	15.0	15.2	14.95	14.5	15.8	a	69.7	41.6	15.6
	10	13.8	14.0	13.25	13.3	13.6	72.6	61.3	30.8	13.2
	100	12.0	11.1	12.4	12.3	12.8	66.0	b	27.0	14.9
	1000	12.05	10.2	11.25	12.8	10.8	64.1	b	25.8	14.7

[a] Data widely scattered. A reliable average could not be determined.

[b] Reliable values could not be determined.

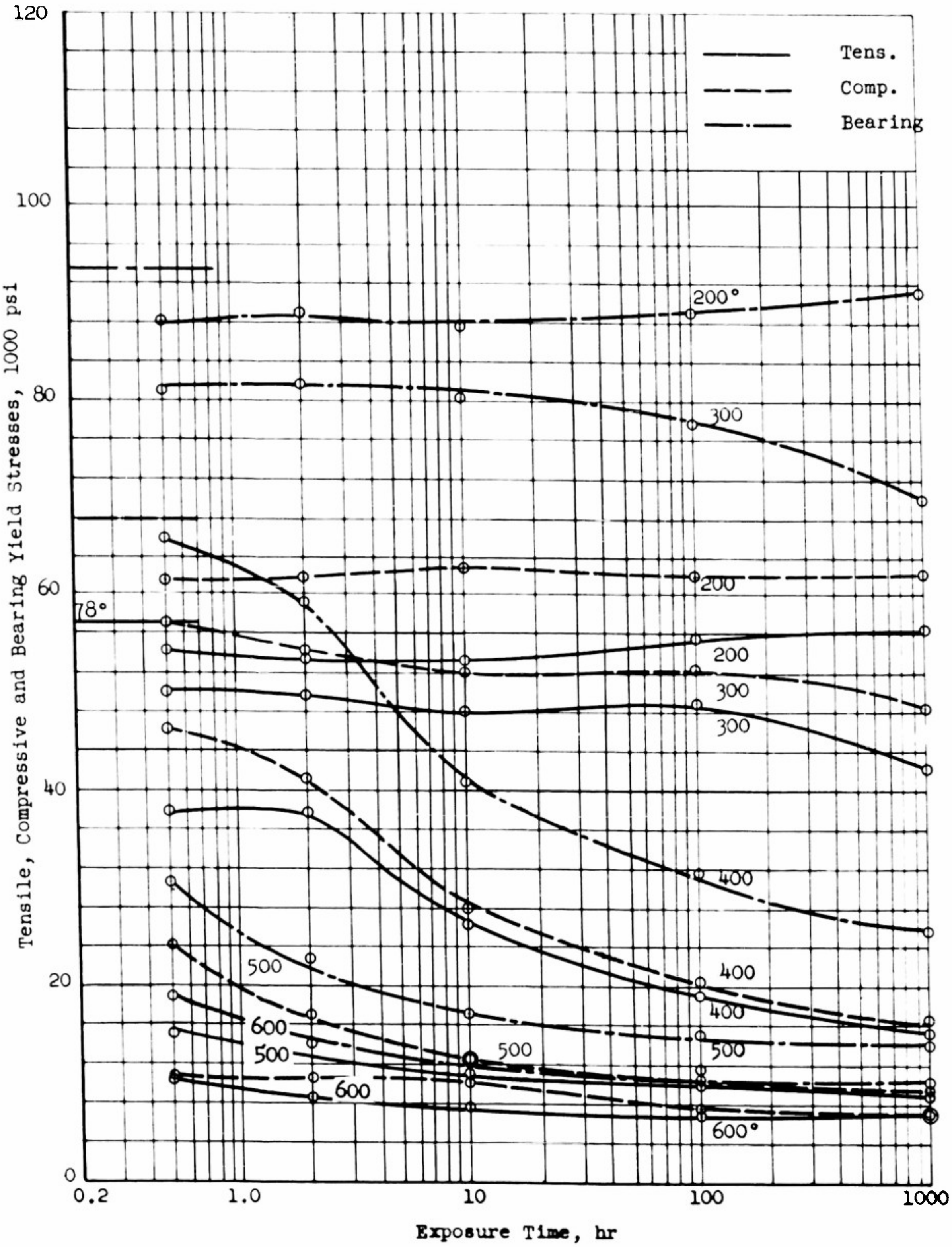

Fig. 6 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON TENSILE, COMPRESSIVE, AND BEARING YIELD STRENGTHS OF 14S-T6 ALUMINUM ALLOY

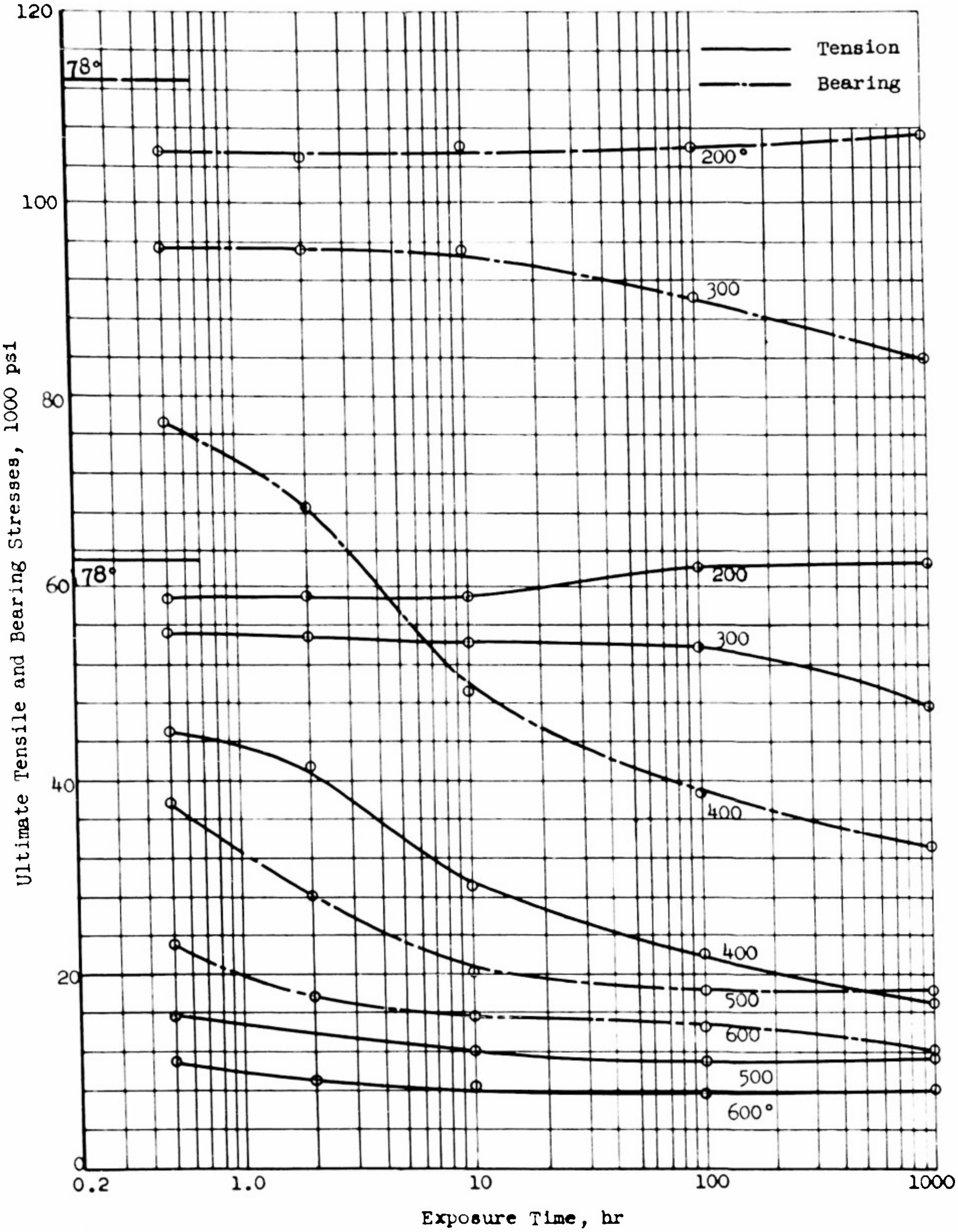

Fig. 7 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND BEARING STRENGTHS OF 14S-T6 ALUMINUM ALLOY

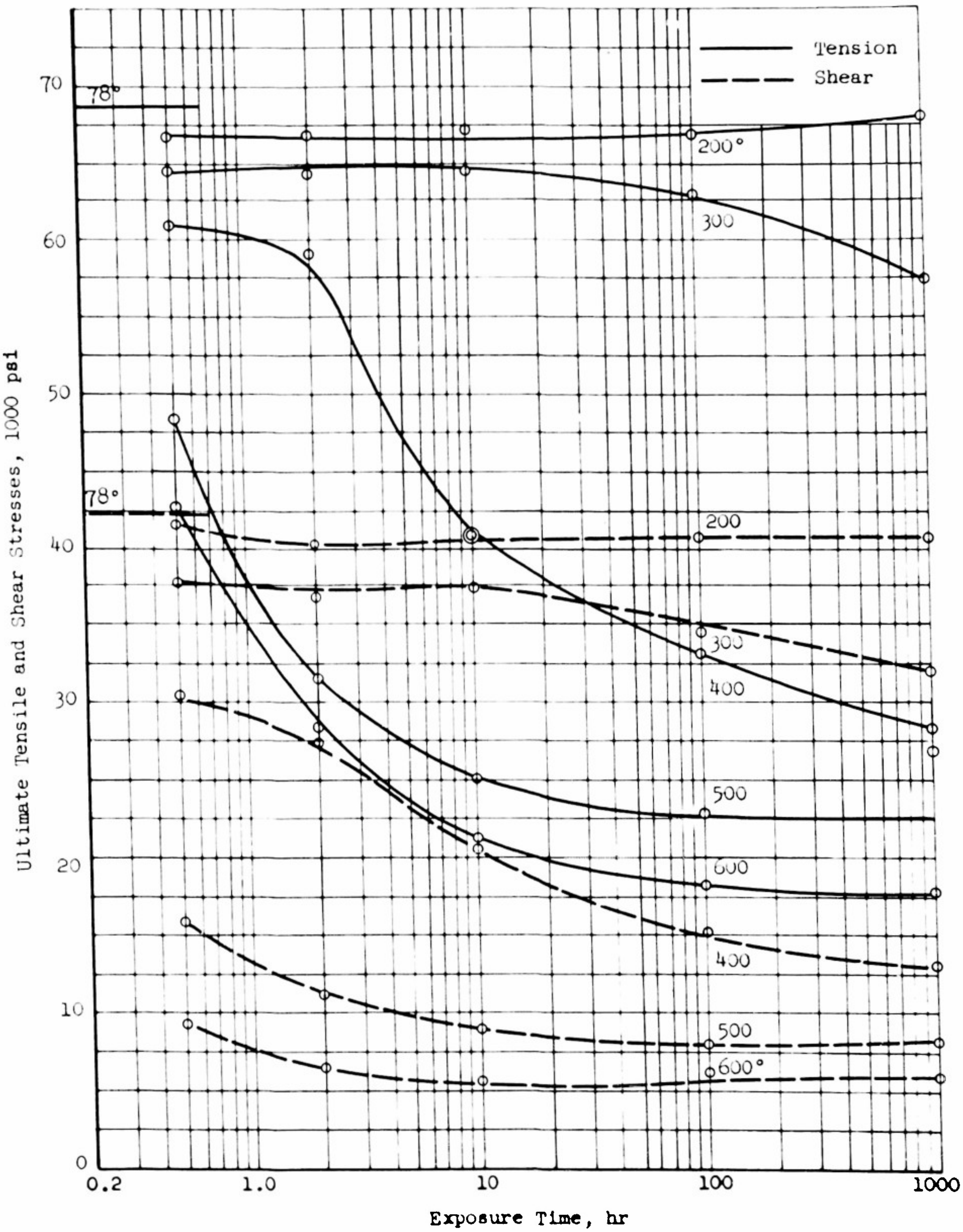

Fig. 8 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND SHEAR STRENGTHS OF 14S-T6 ALUMINUM ALLOY

As temperatures increase, 14S-T6 aluminum alloy loses strength and tempers at an increasing rate. Observe that at 300°F a significant reduction in properties began to occur sometime between 100 and 1000 hours of exposure. At 400°F the properties had diminished substantially after only 10 hours of heating. Data from the 400°F tests indicate that the material suffered its greatest percentile decrease in properties from exposure at this temperature. Moreover, the appearance of the 300° and 400°F curves suggests that longer exposure would have resulted in further reduction of properties. At 500° and 600°F comparatively little decrease occurred after 10 hours of exposure. The appearance of these curves indicates that further exposure would not reduce the properties of the material appreciably below the values observed after 1000 hours of exposure.

For the most part, specimens prepared from sheet of 3/16-inch nominal thickness exhibited the same general characteristics as those made of 0.064-inch sheet. That is, corresponding curves of Figs. 7 and 8 are of the same general shape. However, the 3/16-inch material had greater room temperature tensile strength than the 0.064 inch; it also displayed substantially higher resistance to deterioration of tensile properties under all temperature and exposure conditions. The difference can be observed most readily by comparing values of ultimate tensile strength for corresponding conditions in Table 2. Only for the 100-hour exposure condition at 200°F was the tensile strength of the 0.064-inch material greater percentagewise than that of the 3/16-inch sheet. At higher temperatures, the 3/16-inch material demonstrated marked superiority. Table 2 also shows that the elevated temperature shear properties of 3/16-inch 14S-T6 aluminum alloy are considerably poorer than its tensile properties.

In Table B-2, which presents the results of individual compressive tests, it will be noted that for two conditions at 600°F, yield strength data is listed while modulus data is not. The modulus could not be determined because the early points on the curves were unreliable. However, the material exhibited definite yield characteristics and it was therefore possible to determine the yield strength without knowledge of the modulus.

The manner in which tensile and compressive moduli of elasticity of the alloy are affected by temperature is indicated by Fig. 9. Apparently, a definite but irregular reduction in moduli occurs when the material is exposed to increasing temperatures. It should be remembered that the points on these curves were determined by averaging the moduli values for all exposure conditions at each temperature, and that they do not, therefore, represent any particular condition.

B. Effect of Temperature and Exposure Time on 24S-T81 Aluminum Alloy (Clad)

The average values of mechanical properties observed in tests performed with 24S-T81 aluminum alloy sheet material are expressed in Table 3 as percentages of room temperature results. Graphical data is presented in Figs. 10 through 13.

From the various yield strength and ultimate strength versus exposure time curves for 0.064-inch sheet, it is evident that these basic mechanical properties respond in similar fashion when 24S-T81 aluminum alloy is exposed at elevated temperatures. The material appears to be affected chiefly by temperature up to 300°F. At 400°F, however, its mechanical properties decline progressively as the time of exposure is increased. The decline apparently begins shortly after the material has been exposed for 2 hours.

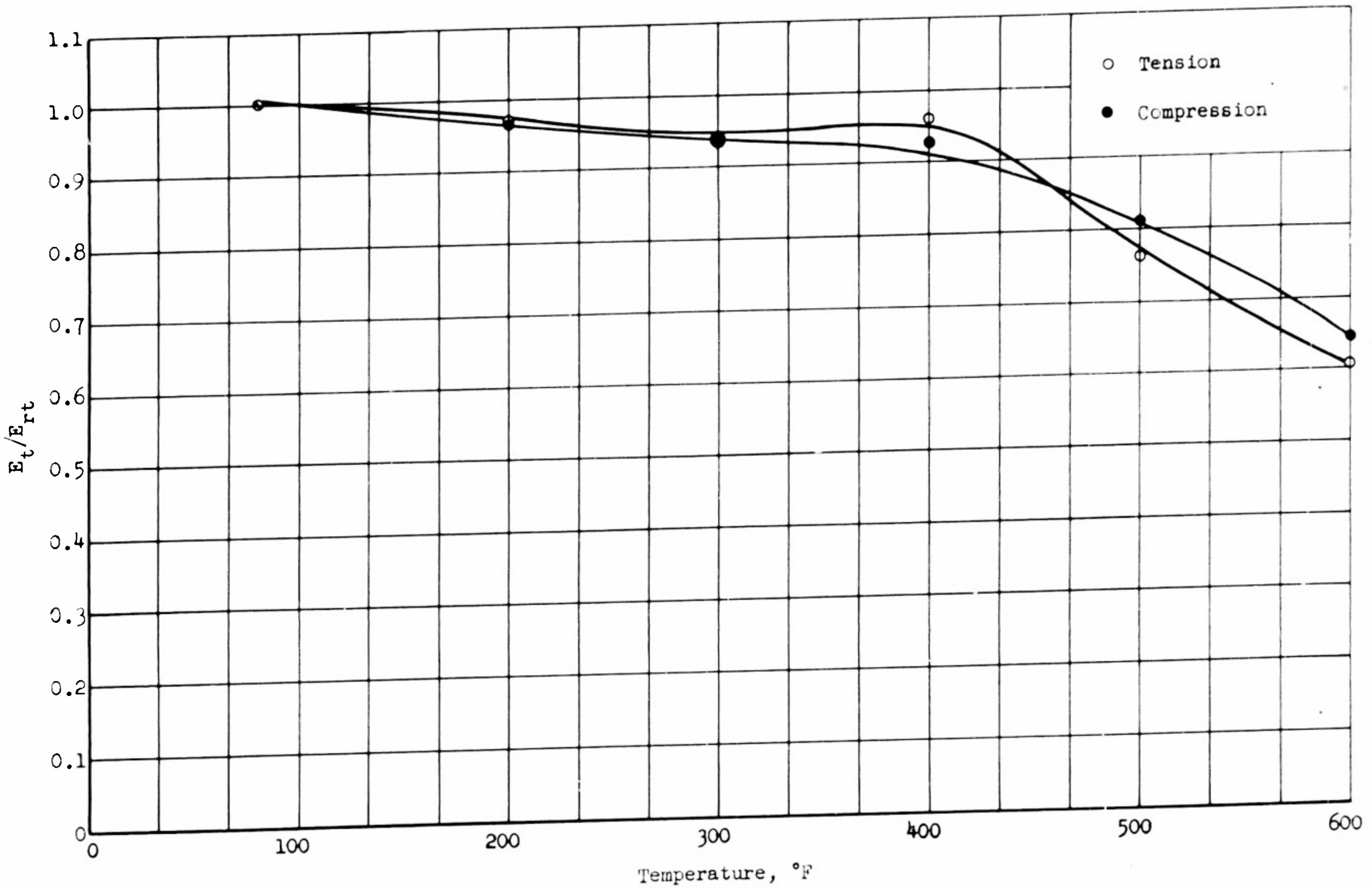

Fig. 9 / EFFECT OF TEMPERATURE ON MODULUS OF ELASTICITY IN TENSION AND COMPRESSION OF XA78S-T6 ALUMINUM ALLOY

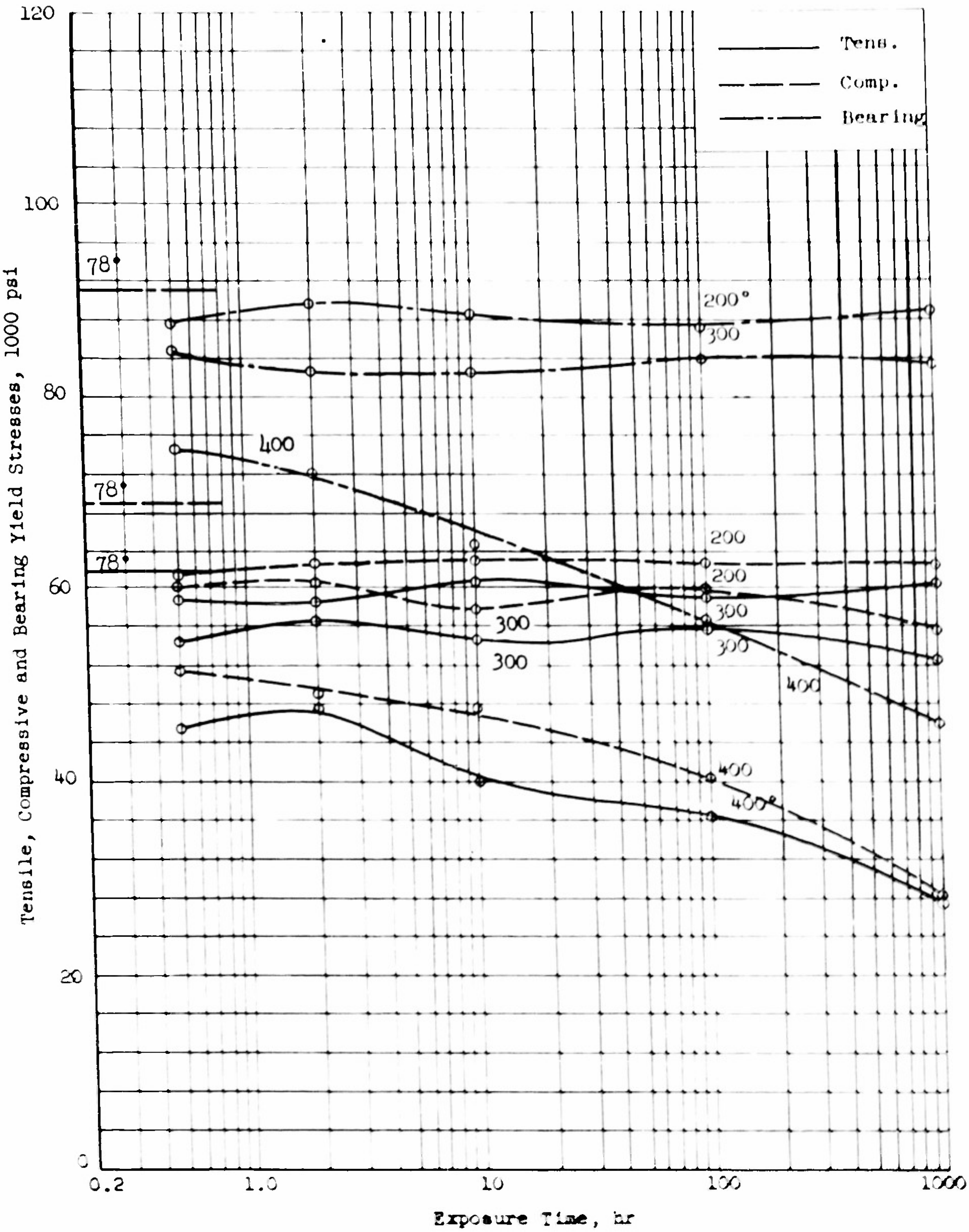

Fig. 10 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON TENSILE, COMPRESSIVE, AND BEARING YIELD STRENGTHS OF 24S-T81 ALUMINUM ALLOY

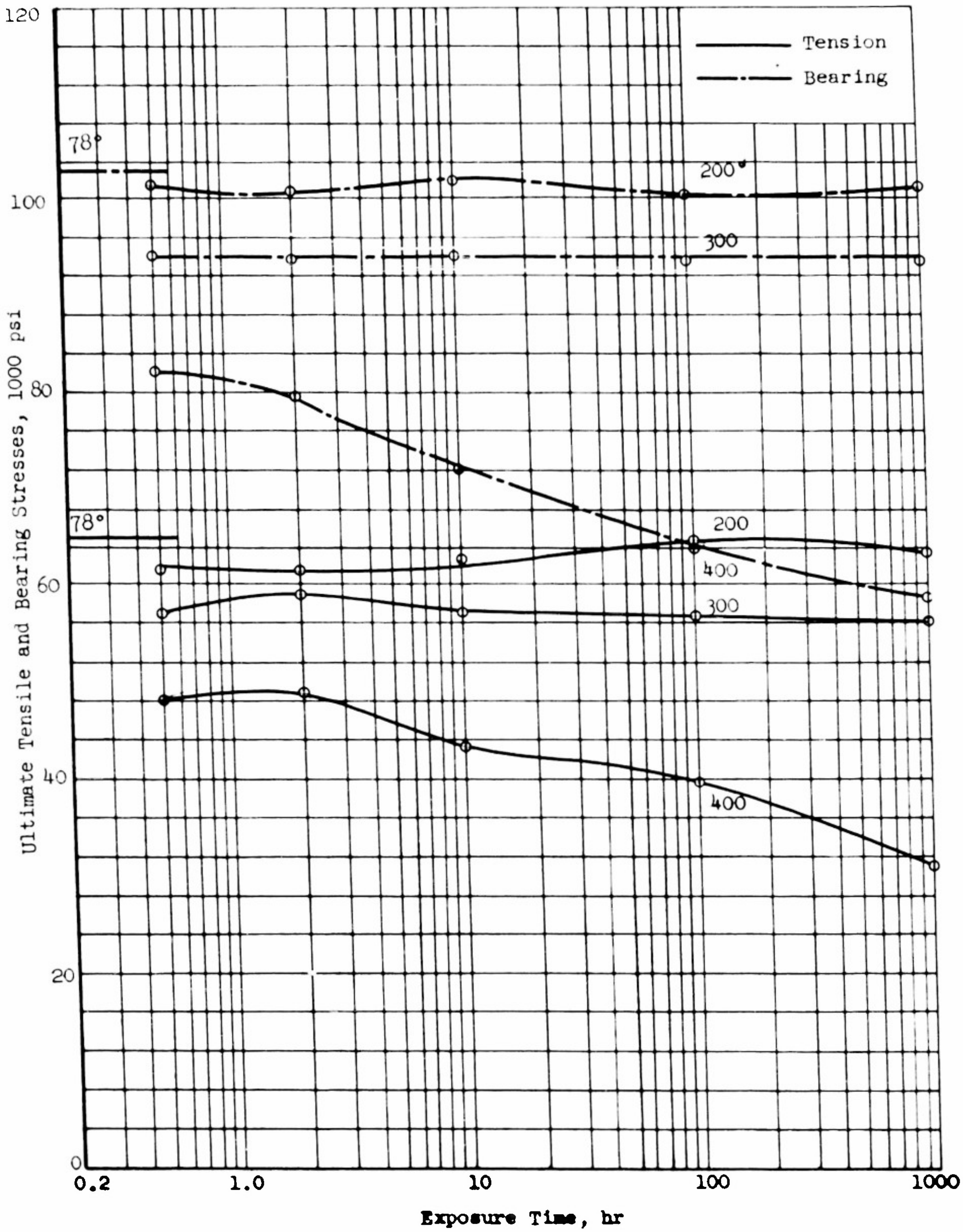

Fig. 11 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND BEARING STRENGTHS OF 24S-T81 ALUMINUM ALLOY

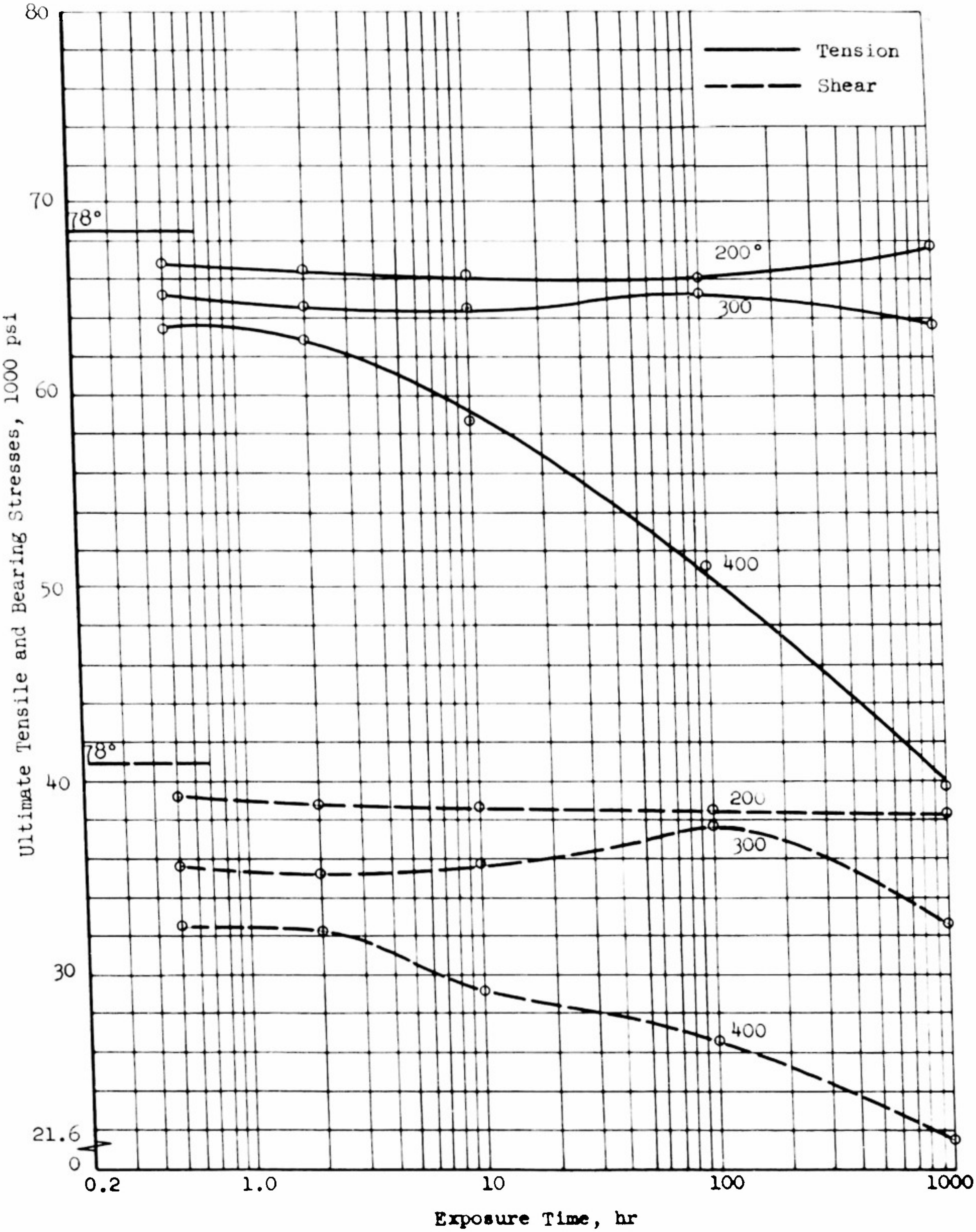

Fig. 12 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND SHEAR STRENGTHS OF 24S-T81 ALUMINUM ALLOY

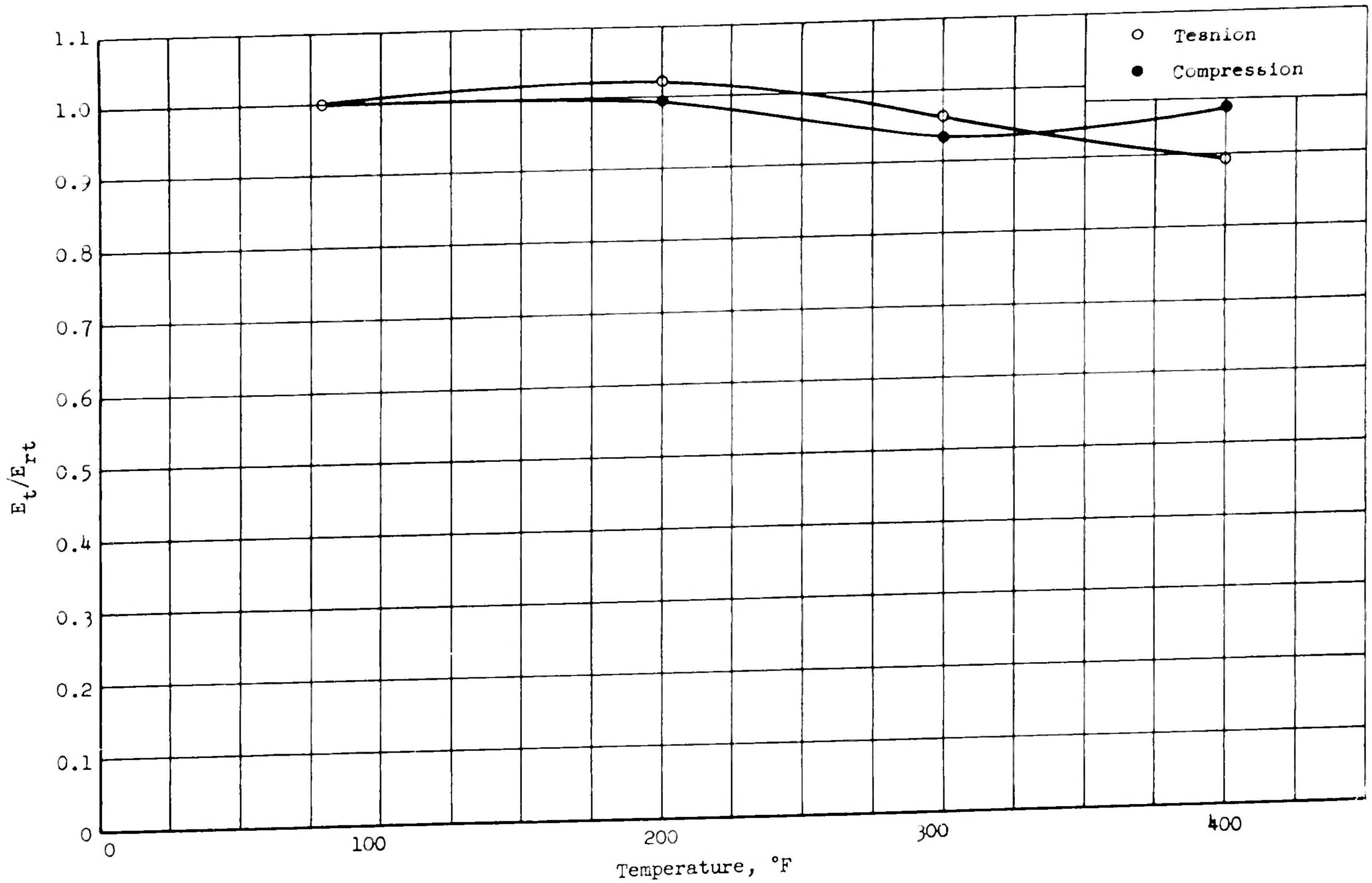

Fig. 13 EFFECT OF TEMPERATURE ON THE TENSILE AND COMPRESSIVE MODULI OF ELASTICITY OF 24S-T81 ALUMINUM ALLOY

It should be noted in Table 3 that the yield tensile, compressive, and bearing strengths, and the ultimate tensile strength of this material are higher after 1000 hours of exposure at 200°F than after 1/2 hour. Although the differences are slight, they are consistent, and therefore suggest that exposing the material for long periods at this temperature may cause mild age hardening.

Data obtained from tests of 3/16-inch 24S-T81 aluminum alloy are, in general, similar to those observed with the 0.064-inch sheet. The results differ in two important respects, however. The 3/16-inch material is stronger, and it exhibits considerably greater resistance to reduction of tensile properties from exposure to elevated temperatures. The shear properties of 3/16-inch material are distinctly inferior to its tensile properties, however, exhibiting greater temperature induced decline. Although the reasons for this are not clear, they may be associated with specimen fabrication. Each shear specimen is lathe-turned to a diameter of 1/8-inch from a blank 3/16-inch thick, and hence does not contain material from the surface layers of the sheet. Since the surface of the sheet is more severely cold worked than the interior, it is possible that the absence of this severely worked surface material, which is known to be quite responsive to the artificial aging of the T81 heat treatment, is in part responsible for the relatively poor performance of the 3/16-inch 24S-T81 in shear.

From Fig. 13, which shows tensile and compressive moduli of elasticity as a function of temperature, it can be inferred that the tensile modulus decreases steadily with increasing temperature. No clear trend is evident, however, from the appearance of the compressive modulus graph. A matter of some interest concerns the 200°F point on the tensile modulus

Table 3

MECHANICAL PROPERTIES OF 24S-T81 CLAD ALUMINUM ALLOY SHEET FOR VARIOUS TEMPERATURES AND EXPOSURE TIMES EXPRESSED AS A PERCENTAGE OF ROOM TEMPERATURE VALUES

Temp °F	Exposure Time, hr	Yield Strength			Ultimate Strength		Modulus of Elasticity		Ultimate Strength, 3/16 in.	
		Tensile	Compressive	Bearing	Tensile	Bearing	Tensile	Compressive	Tensile	Shear
78		61,900 psi	69,300 psi	91,200 psi	65,600 psi	103,000 psi	10.2×10^6 psi	10.6×10^6 psi	68,400 psi	40,800 psi
200	0.5	95.0	89.0	96.2	93.6	98.5	100.4	96.2	97.7	96.3
	2	94.5	91.4	98.8	93.6	97.7	109.8[a]	101.9	97.0	95.1
	10	97.7	91.3	96.8	95.5	99.1	102.0	98.0	96.9	95.1
	100	95.0	89.9	95.6	98.5	97.3	101.0	100.0	96.9	94.4
	1000	97.7	89.9	97.9	97.0	98.4	105.9	101.8	99.0	93.6
300	0.5	88.3	86.0	93.0	87.0	91.3	88.2	95.3	95.5	87.5
	2	90.9	87.3	90.8	89.7	91.0	101.0	89.6	94.3	86.5
	10	87.9	82.8	90.6	86.6	91.1	96.0	97.1	94.1	87.5
	100	90.2	86.2	92.1	85.9	91.0	98.0	95.3	95.2	92.4
	1000	87.7	79.6	91.5	85.3	91.1	98.0	89.6	93.2	84.5
400	0.5	73.4	74.7	81.5	73.1	79.8	91.1	98.0	92.9	79.7
	2	76.6	70.9	79.3	74.4	77.5	96.0	96.2	92.0	79.0
	10	64.7	68.8	70.6	66.0	69.9	96.5	101.0	85.7	71.5
	100	59.0	57.8	61.8	60.3	62.3	88.2	85.8	74.7	65.2
	1000	44.9	40.8	50.4	47.1	56.7	73.5	100.0	58.0	53.0

[a] Questionable value.

curve. Not only is the average modulus for this temperature higher than the room temperature modulus, a fact readily perceivable from the curve, but the moduli for all exposure conditions at this temperature are higher. In other words, every value used in the computation of the 200°F average was higher than the average room temperature modulus. This behavior was not observed with any other material, and hence there is scant likelihood that it is typical of 24S-T81 aluminum. Probably the specimens tested at room temperature had tensile moduli which were somewhat lower than normal, while the moduli of the 200°F specimens were slightly higher than normal.

C. Effect of Temperature and Exposure Time on 24S-T86 Aluminum Alloy (Clad)

Average value data from tests of 24S-T86 aluminum alloy is presented in Table 4 and in Figs. 14 through 17. The tabulated results and the graphs show that at each temperature the various yield strengths and ultimate strengths are affected in much the same fashion. At 200°F, exposure time appears to have little influence. At 300°F, temperature is again the most important factor, until the material has been exposed for 100 hours. A significant reduction in properties occurs sometime during the interval between 100 and 1000 hours. At 400°F, the properties seem to remain independent of exposure time for 2 hours, but decrease substantially after 10 hours have passed.

Again, the 3/16-inch material, while behaving in approximately the same fashion as the 0.064 inch, exhibited higher strength and superior resistance to diminution of tensile properties from continued exposure at elevated temperatures. Its performance in shear was less satisfactory than in tension, however, perhaps for the reason previously suggested.

Table 4

MECHANICAL PROPERTIES OF 24S-T86 CLAD ALUMINUM ALLOY SHEET FOR VARIOUS TEMPERATURES AND EXPOSURE TIMES EXPRESSED AS A PERCENTAGE OF ROOM TEMPERATURE VALUES

Temp °F	Exposure Time, hr	Yield Strength			Ultimate Strength		Modulus of Elasticity		Ultimate Strength, 3/16 in.	
		Tensile	Compressive	Bearing	Tensile	Bearing	Tensile	Compressive	Tensile	Shear
78		69,100 psi	74,500 psi	100,200 psi	72,700 psi	113,000 psi	11.2×10^6 psi	10.5×10^6 psi	74,850 psi	45,300 psi
200	0.5	91.8	94.5	97.0	93.5	97.7	88.4	99.0	98.7	95.1
	2	92.0	95.6	94.7	93.5	95.7	91.0	103.8	97.7	95.4
	10	92.9	93.5	96.9	94.2	98.7	92.9	98.1	98.0	95.4
	100	92.5	94.5	95.2	94.2	95.5	90.1	97.2	99.5	95.1
	1000	93.7	94.4	96.7	95.6	97.0	95.5	96.1	100.9	96.2
300	0.5	89.6	93.0	93.9	89.4	93.0	92.0	93.8	95.2	90.7
	2	89.6	91.0	89.9	87.5	90.5	92.9	100.0	95.8	88.4
	10	89.5	90.1	92.0	86.1	91.6	90.1	96.1	94.9	94.5
	100	90.2	90.4	92.2	87.8	91.4	92.9	96.1	94.0	92.0
	1000	81.7	82.4	83.0	79.0	83.3	94.6	99.0	89.1	77.3
400	0.5	76.6	81.4	81.2	74.8	79.3	85.7	100.0	92.8	81.7
	2	74.7	72.6	73.1	71.2	72.0	85.7	100.0	91.8	71.5
	10	60.4	63.9	64.8	60.6	64.5	88.4	98.1	79.0	60.5
	100	54.3	55.5	60.1	56.5	61.1	89.3	97.2	71.7	57.6
	1000	40.2	36.1	46.4	41.4	48.5	75.0	112.3*	52.4	41.7

*Questionable value.

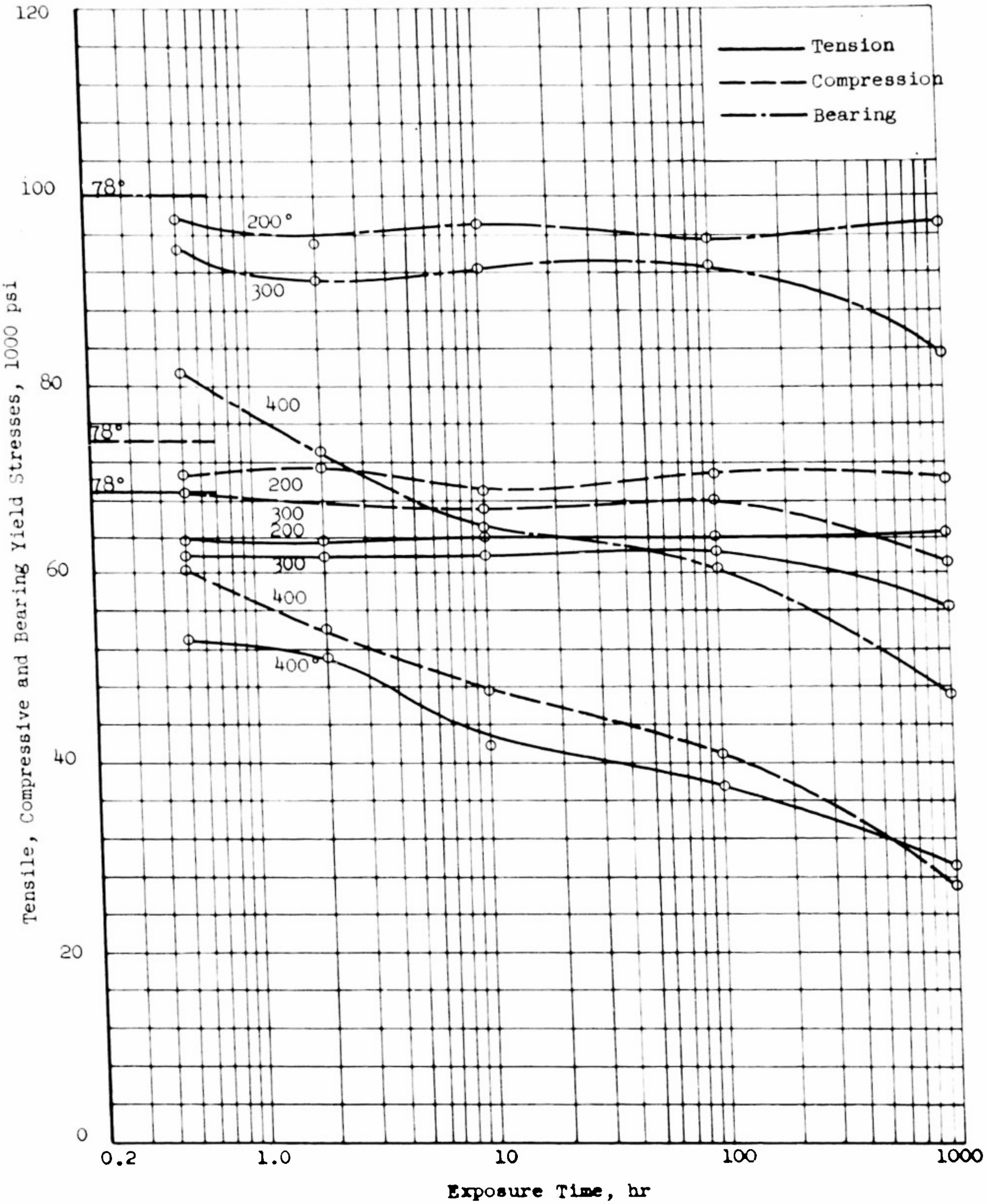

Fig. 14 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON TENSILE, COMPRESSIVE, AND BEARING YIELD STRENGTHS OF 24S-T86 ALUMINUM ALLOY

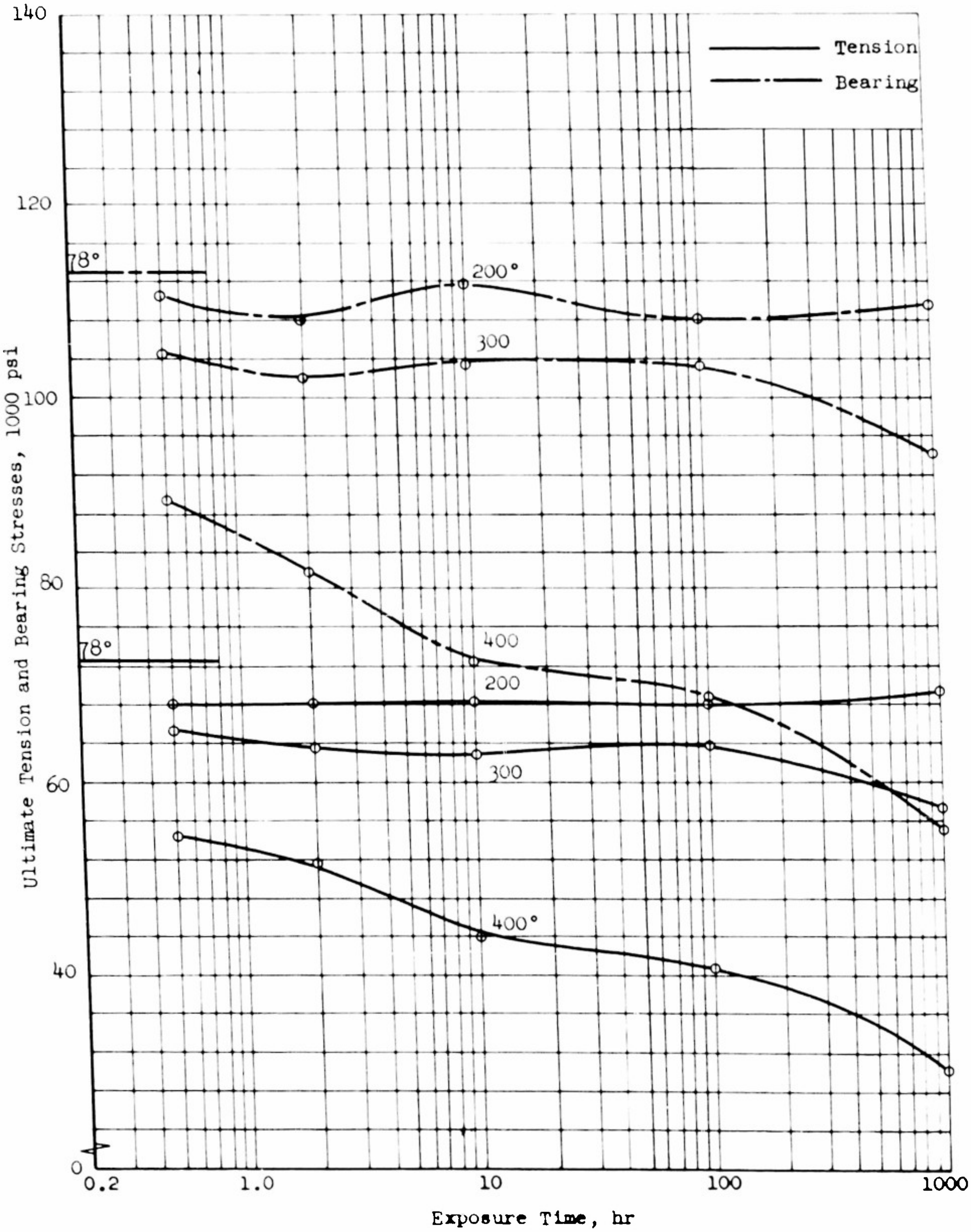

Fig. 15 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND BEARING STRENGTHS OF 24S-T86 ALUMINUM ALLOY

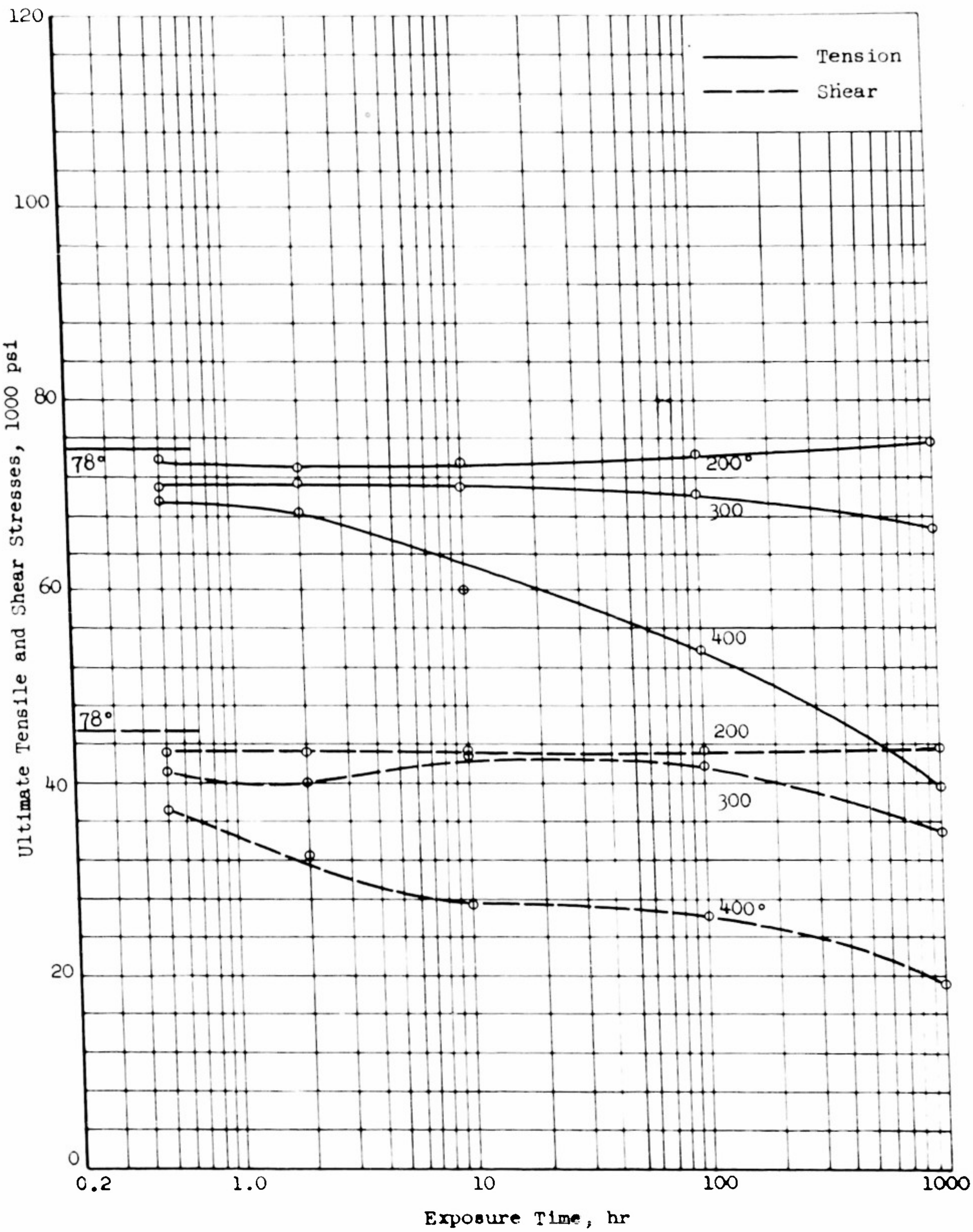

Fig. 16 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND SHEAR STRENGTHS OF 24S-T86 ALUMINUM ALLOY

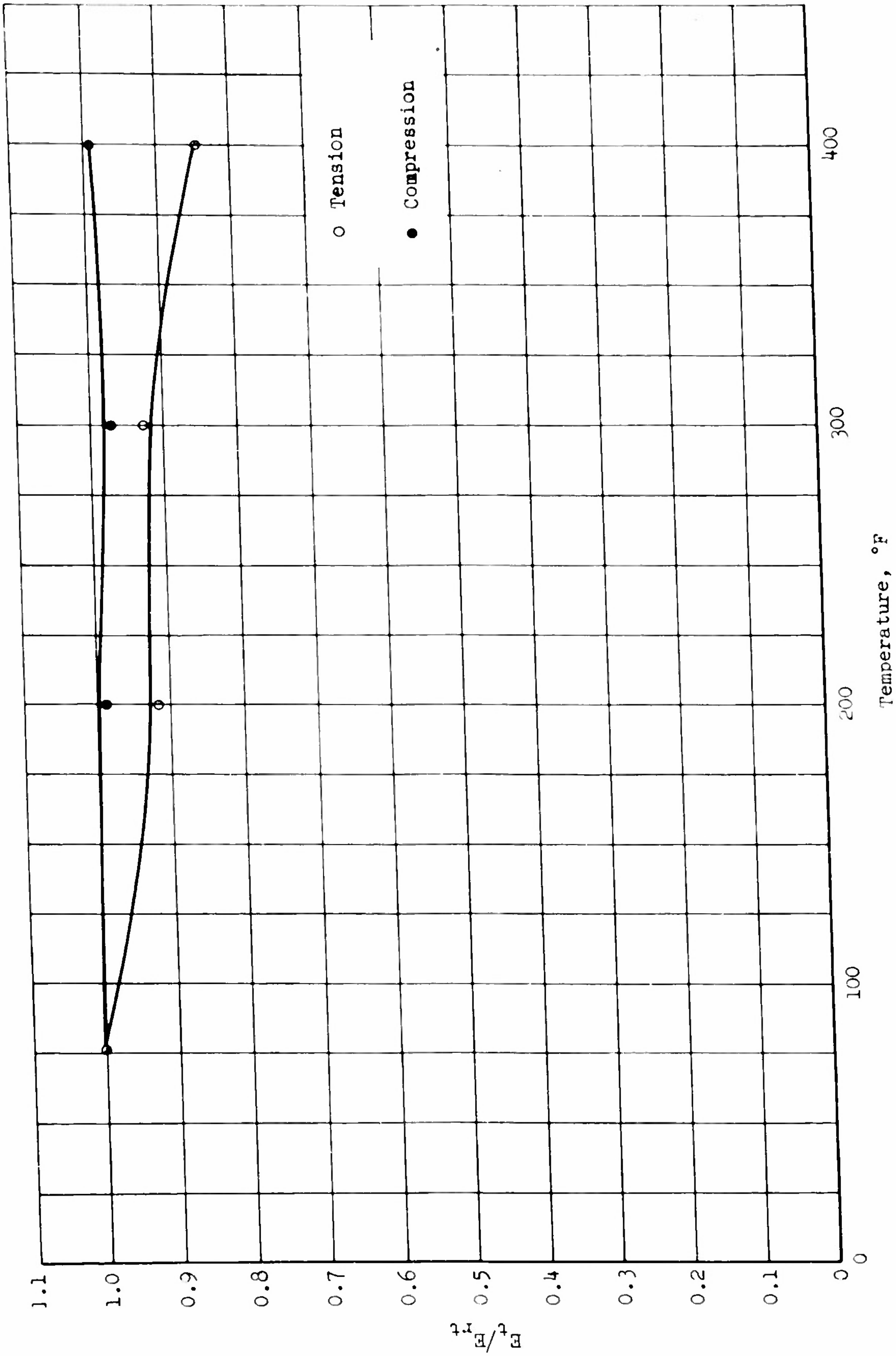

Fig. 17 EFFECT OF TEMPERATURE ON THE TENSILE AND COMPRESSIVE MODULI OF ELASTICITY OF 24S-T86 ALUMINUM ALLOY

The relationship between the tensile and compressive moduli of elasticity and temperature is illustrated graphically in Fig. 17. Observe that the tensile modulus tended to diminish with increasing temperature, but not in a uniform fashion. The compressive modulus remained quite stable over the entire range of test temperatures. It should be borne in mind, however, that the points on these curves represent average values, and therefore cannot be considered representative of all exposure conditions. More detailed information can be found in the tables of Appendix B, which present the results of individual tests.

D. Comparison of the Elevated Temperature Properties of 24S-T81 and 24S-T86 Aluminum Alloy Sheet Materials

The 24S-T86 alloy, it will be recalled, differed from the 24S-T81 alloy only in final temper. Both materials are the same in nominal composition and both are given the same basic heat treatment, designated T8. The T8 process consists of solution heat treatment, then cold work, and finally artificial aging. The properties which result from the T8 process can be modified by varying the amount of cold work and/or the aging conditions. The last digit of the treatment designation indicates the final temper of the material.

According to the heat treatment recommendations published by the Aluminum Company of America in the booklet, "Alcoa Aluminum and Its Alloys," the T81 and T86 conditions can be produced from solution-treated, cold-worked 24S aluminum by aging at 375°F for different periods of time. The T86 condition results from aging for 7 to 9 hours, while the T81 condition is obtained by heating for 11 to 13 hours. Since the properties obtained by the T6 treatment are higher than those of the T81 treatment, it appears

that the longer heating period results in tempering (softening and reduction in properties) of the material. It is reasonable to suppose, therefore, that after long subsequent exposure at a temperature near the artificial aging temperature, the 24S-T81 and 24S-T86 alloys might exhibit substantially the same properties. That is, the difference in total times of exposure would then be small percentagewise. Of course, the lack of continuity of the heating might also exert considerable influence. Nevertheless, it is interesting to compare the properties of these materials after 100 and 1000 hours of exposure at 400°F. This is the test temperature nearest the 375°F aging temperature. Such a comparison is presented in Table 5.

Observe that after 100 hours, the differences between all properties except the bearing strength of these materials are slight, the properties of 24S-T86 evidently remaining superior. However, after 1000 hours, most properties of the two alloys are the same for all practical purposes. Curiously, the 24S-T81 alloy exhibits higher ultimate bearing and shear strengths than the 24S-T86 for this condition. Examination of the results of tests performed at 300°F shows that after 1000 hours of exposure many of the properties of these two alloys become nearly the same at this temperature also.

E. Results of Mechanical Properties Tests of FS1-H24 Magnesium Alloy at 200°F

The average values determined from mechanical properties tests of several materials conducted at 200°F are presented in Table 6. These materials had been tested in the first phase of the program at other temperatures; data from the earlier tests may be found in AF Technical Report No. 6517, Part 1. The 200°F data were intended to augment the store of information previously obtained.

Table 5

COMPARISON OF PROPERTIES OF 24S-T81 AND 24S-T86 ALUMINUM ALLOYS
AFTER 100 AND 1000 HOURS EXPOSURE AT 400°F

Material	Exposure Time, hr	Yield Strength, psi			Ultimate Strength, psi		Ultimate Strength, 3/16 in. psi	
		Tensile	Compressive	Bearing	Tensile	Bearing	Tensile	Shear
24S-T81	100	36,500	40,050	56,400	39,600	64,200	51,100	26,600
	1000	27,400	28,300	46,000	30,900	58,400	39,700	21,600
24S-T86	100	37,500	41,300	60,300	41,100	69,050	53,600	26,100
	1000	27,800	26,900	46,500	30,100	54,800	39,200	18,900

Table 6

MECHANICAL PROPERTIES OF FS1-H24 MAGNESIUM ALLOY, 75S-T6 ALUMINUM ALLOY, COLD ROLLED TITANIUM, AND ANNEALED TITANIUM AT 200°F FOR VARIOUS EXPOSURE TIMES, EXPRESSED AS A PERCENTAGE OF ROOM TEMPERATURE VALUES

Material	Temp °F	Exposure Time, hr	Yield Strength Tensile	Yield Strength Compressive	Yield Strength Bearing	Ultimate Strength Tensile	Ultimate Strength Bearing	Modulus of Elasticity Tensile	Modulus of Elasticity Compressive	Ultimate Strength, 3/16 in. Tensile	Ultimate Strength, 3/16 in. Shear
FS1-H24 Magnesium	78*		32,700 psi	25,550 psi	46,200 psi	41,200 psi	58,000 psi	6.6×10^6 psi	6.9×10^6 psi	43,500 psi	23,300a psi
	200	0.5	75.9	88.2	87.0	85.2	95.0	106.0	81.2	90.6	98.2
		1000	79.8	91.2	85.5	81.0	90.0	95.5	75.4	89.2	94.9
75S-T6 Aluminum	78*		63,200 psi	70,750 psi	93,200 psi	72,200 psi	116,900 psi	10.2×10^6 psi	10.8×10^6 psi	76,600 psi	47,300 psi
	200	0.5	97.9	94.6	99.0	91.7	94.5	99.0	89.8	98.1	96.4
		2	96.9	87.6	98.0	91.1	95.0	98.0	94.0	97.0	95.8
		10	95.5	92.7	96.8	93.2	92.5	96.0	89.8	97.8	96.9
		100	95.2	94.9	97.1	92.8	94.7	94.6	91.6	96.3	99.5
		1000	87.8	90.5	102.1	90.5	96.9	90.2	92.6	98.9	98.9
Cold Rolled Titanium	78*		90,300 psi	88,500 psi	129,000 psi	102,700 psi	146,800 psi	16.4×10^6 psi	15.8×10^6 psi	105,200 psi	57,400 psi
	200	0.5	79.0	85.8	86.8	74.7	85.2	105.4	87.4	89.9	95.5
		100	87.2	87.5	86.3	84.0	85.2	91.5	94.3	90.5	111.5
Annealed Titanium	78*		62,600 psi	57,400 psi	94,200 psi	76,200 psi	134,300 psi	16.3×10^6 psi	16.8×10^6 psi	76,000 psi	54,700 psi
	200	0.5	77.0	44.8	[illegible]	88.2	68.6	101.2	82.1	84.0	104.0
		100	79.2	98.4	72.5	84.8	72.5	97.0	85.1	84.4	95.4

*Room temperature values are reproduced from AF Technical Report No. 6517, Part 1, except as specifically noted.
[a]Room temperature rivet shear strength of FS1-H24 magnesium alloy determined from tests performed during subject program.

Tests of FS1-H24 magnesium were performed for only two exposure conditions, 0.5 and 1000 hours. The results indicate that at 200°F, temperature alone causes an appreciable reduction in all properties except the ultimate shear strength of 1/4-inch material. Strangely, this property exhibited a significant increase for both exposure periods. The effect of exposure time is difficult to assess. Tensile and compressive yield strengths were higher after 1000 hours of exposure than after 0.5 hour. All other properties decreased. It would have been advantageous to perform tests for exposure conditions intermediate to 0.5 and 1000 hours. On the basis of present information, however, exposure time appears to be of limited influence at this temperature.

F. Effect of Exposure Time on the Properties of 75S-T6 Aluminum Alloy at 200°F

The results of tests conducted on 75S-T6 aluminum alloy sheet material at 200°F are presented in Table 6 and shown graphically in Figs. 18 through 21. On the last figure, the points for other temperatures were determined from data tabulated in Part 1 of AF Technical Report 6517.

It appears from the curves that at 200°F the properties of 75S-T6 aluminum alloy sheet material are affected chiefly by temperature. The reduction is slight, however. For only one property and exposure condition, tensile yield strength after 1000 hours, does it exceed 9%. Moreover, the reductions in yield bearing strength and in the ultimate tensile and shear strengths of 3/16-inch are almost negligible. Exposure time apparently does not affect the mechanical properties of 75S-T6 aluminum either consistently or significantly at this temperature. The tensile yield strength curve shows a distinct but very slight decline for exposure periods to and

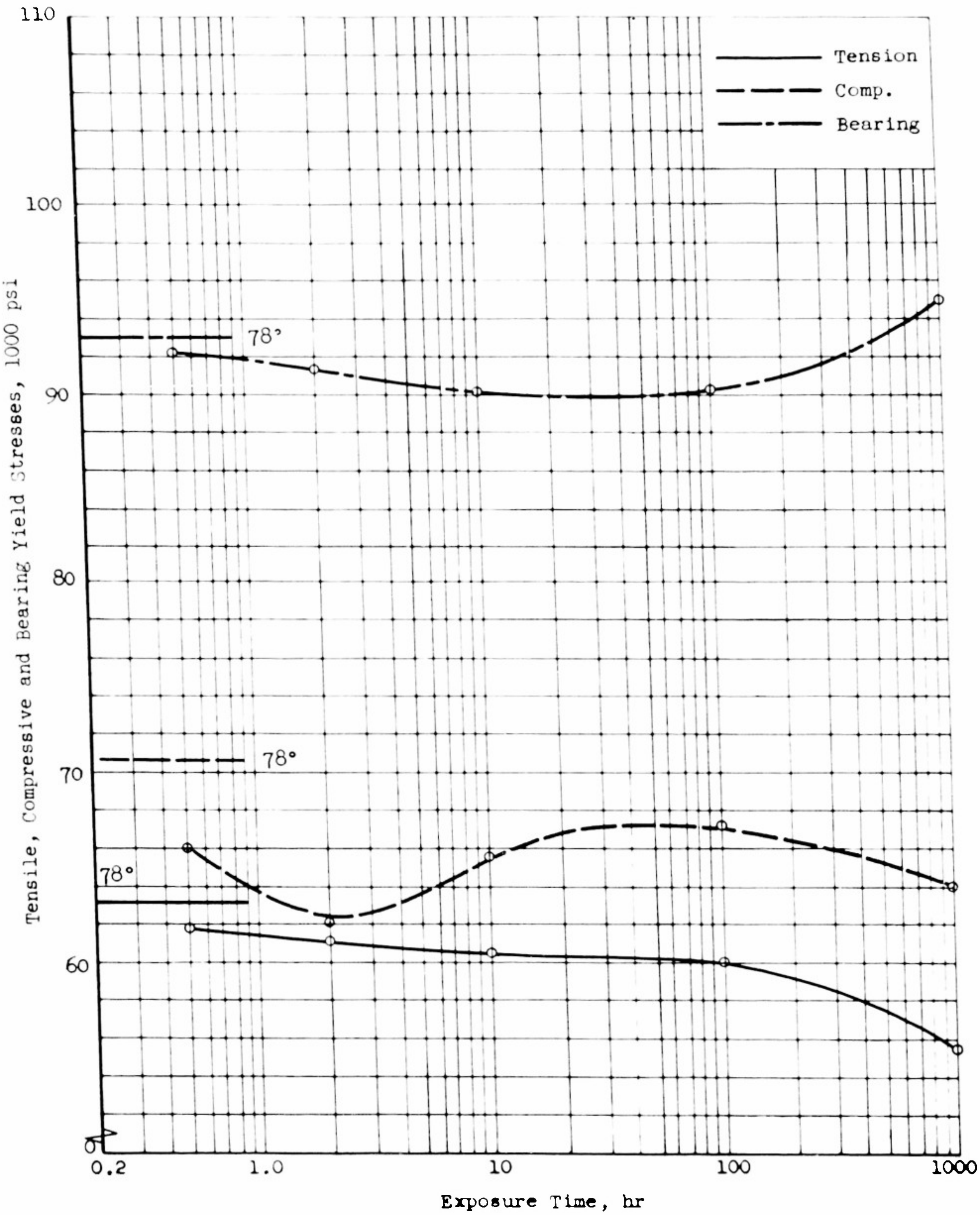

Fig. 18 EFFECT OF EXPOSURE TIME ON TENSILE, COMPRESSIVE, AND BEARING YIELD STRENGTHS OF 75S-T6 ALUMINUM ALLOY AT 200°F

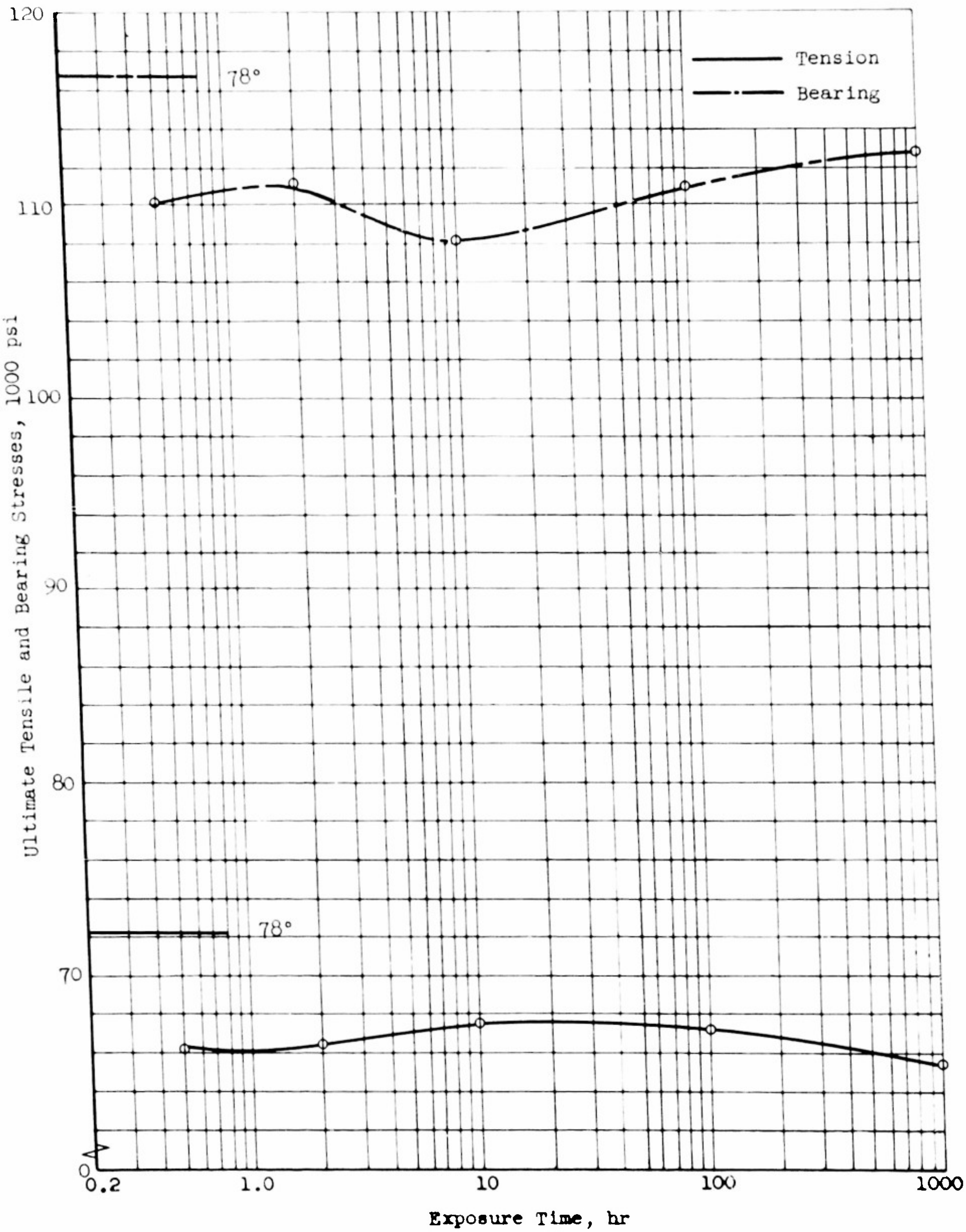

Fig. 19 EFFECT OF EXPOSURE TIME ON ULTIMATE TENSILE AND BEARING STRENGTHS OF 75S-T6 ALUMINUM ALLOY AT 200°F

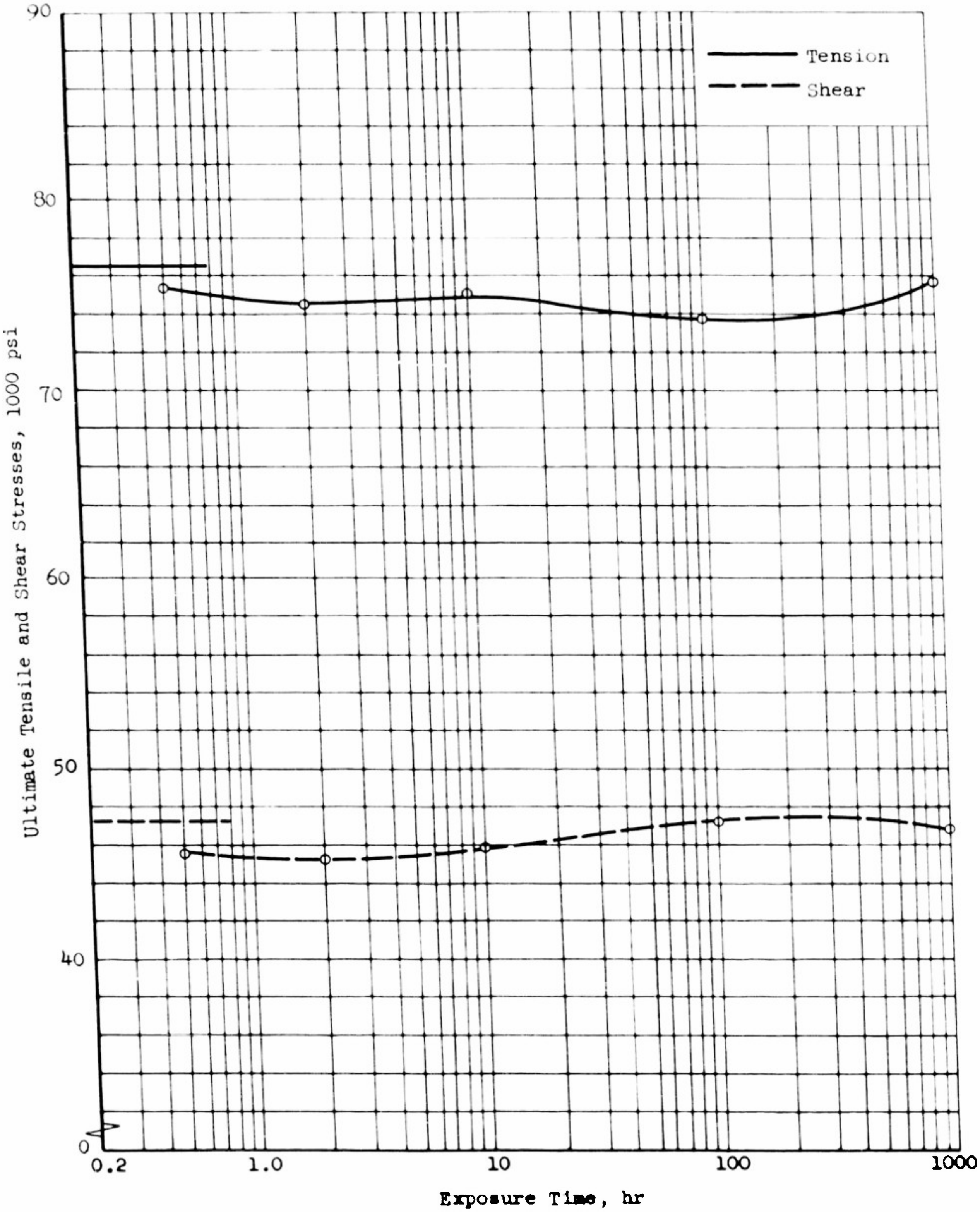

Fig. 20 EFFECT OF EXPOSURE TIME ON ULTIMATE TENSILE AND SHEAR STRENGTHS OF 75S-T6 ALUMINUM ALLOY AT 200°F

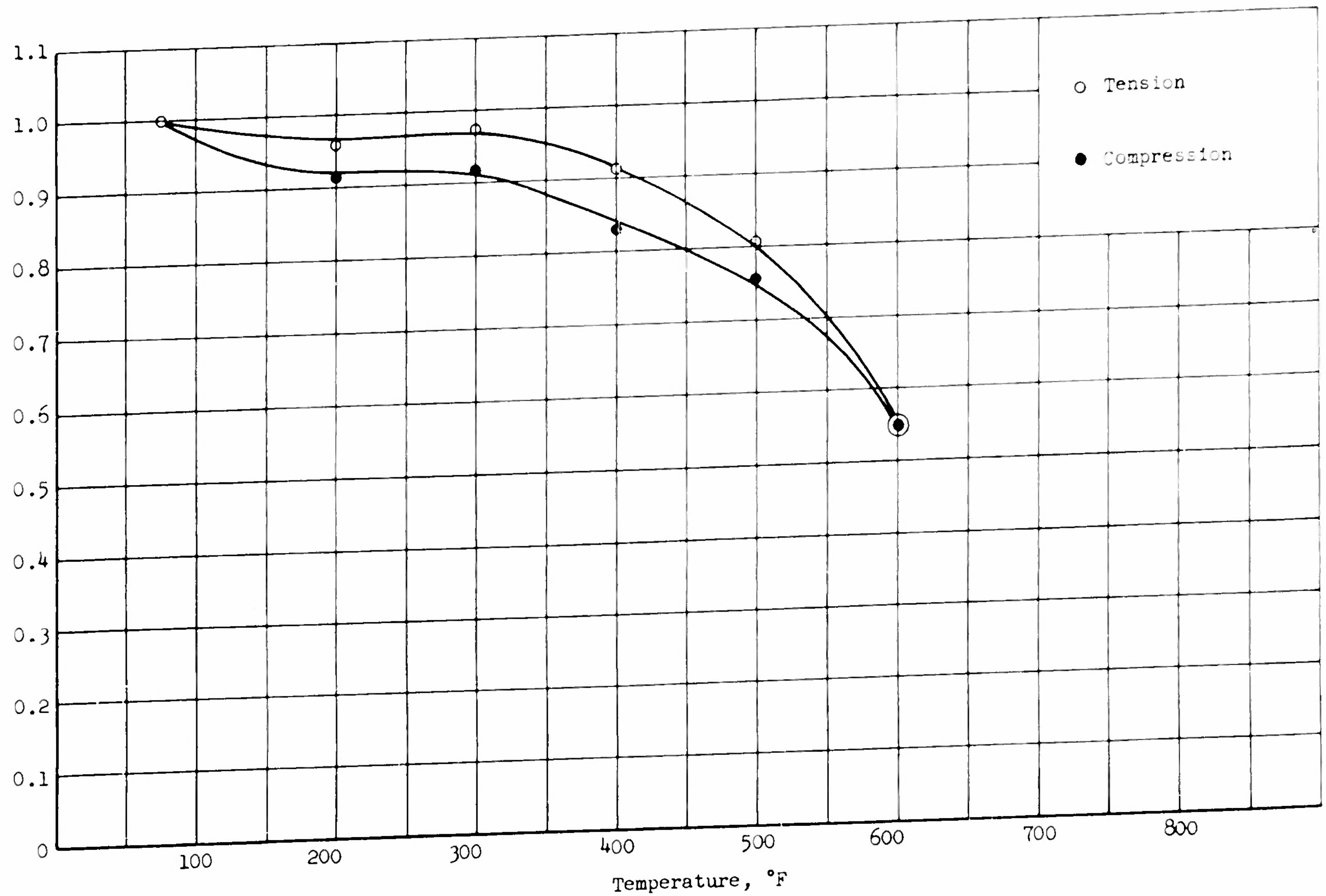

Fig. 21 EFFECT OF TEMPERATURE ON THE TENSILE AND COMPRESSIVE MODULI OF ELASTICITY OF 75S-T6 ALUMINUM ALLOY

including 100 hours, whereupon a noticeable reduction occurs. However, none of the other properties exhibits a definite trend.

Figure 21 indicates that the tensile and compressive moduli of elasticity vary in the same fashion as functions of temperature. Although the tensile curve lies above the compressive throughout most of its range, the actual values of the two moduli are nearly the same. The reason for this is that the compressive modulus is larger than the tensile modulus at room temperature.

G. Results of Mechanical Properties Tests of Cold Rolled Titanium at 200°F

Average value data from tests conducted at 200°F on cold rolled titanium sheet material are presented in Table 6. The 200°F results, together with data from the first phase of the program, were used to construct Figs. 22 to 25. These diagrams depict the relationship between various mechanical properties and temperature for the two exposure conditions investigated, 0.5 and 100 hours. In AF Technical Report 6517, Part 1, similar curves were constructed without information on the properties at 200°F. Figures 22 to 25, some of which differ widely from the earlier graphs in certain temperature ranges, can be considered to supersede the previous curves.

The graphical data indicates that the mechanical properties of annealed titanium decrease progressively with increasing temperature. The curves are markedly dissimilar in shape, however. It can be observed that the properties differ considerably with respect to the percentile reductions which occur in the various temperature intervals.

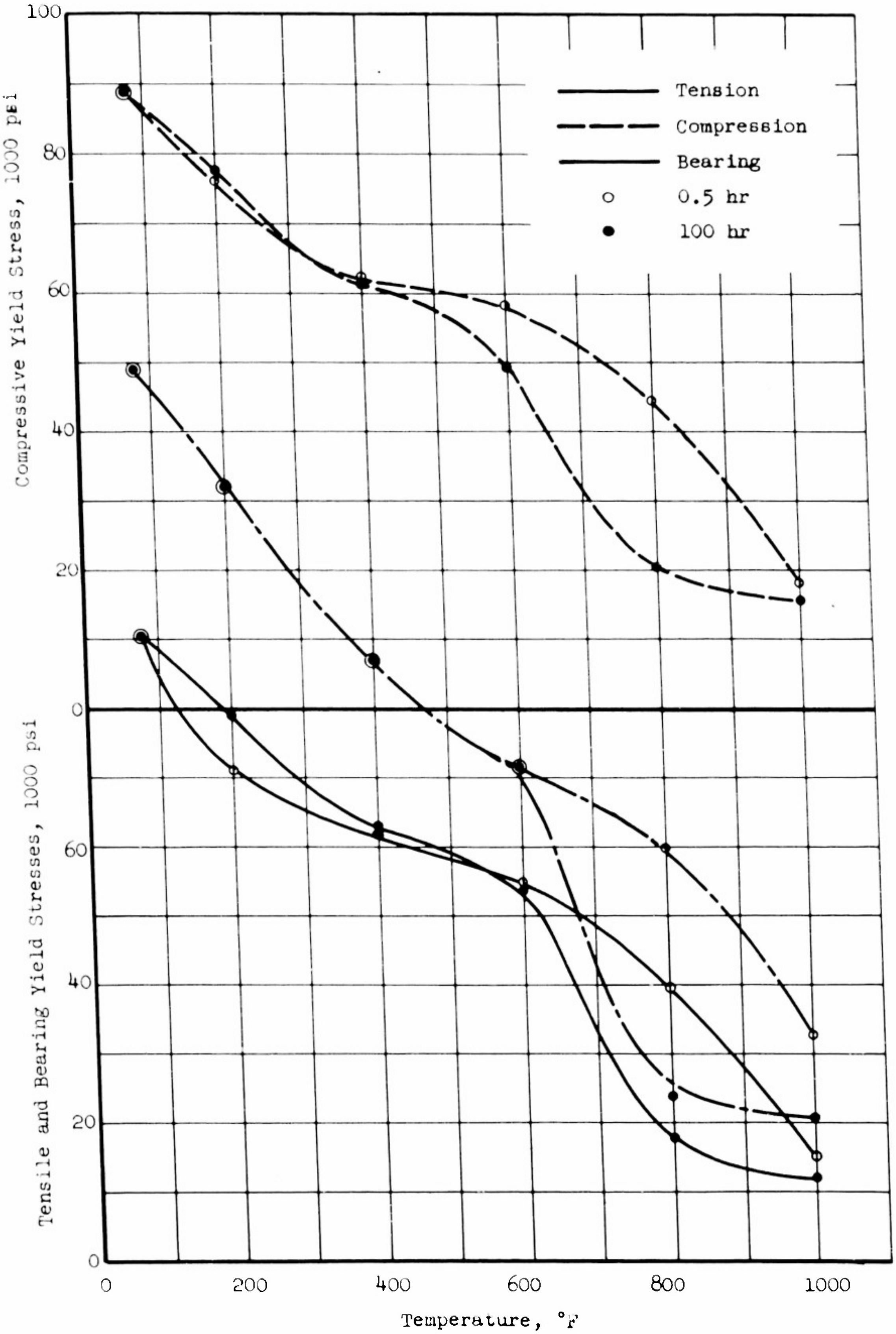

Fig. 22 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON TENSILE, COMPRESSIVE AND BEARING YIELD STRENGTHS OF COLD ROLLED TITANIUM

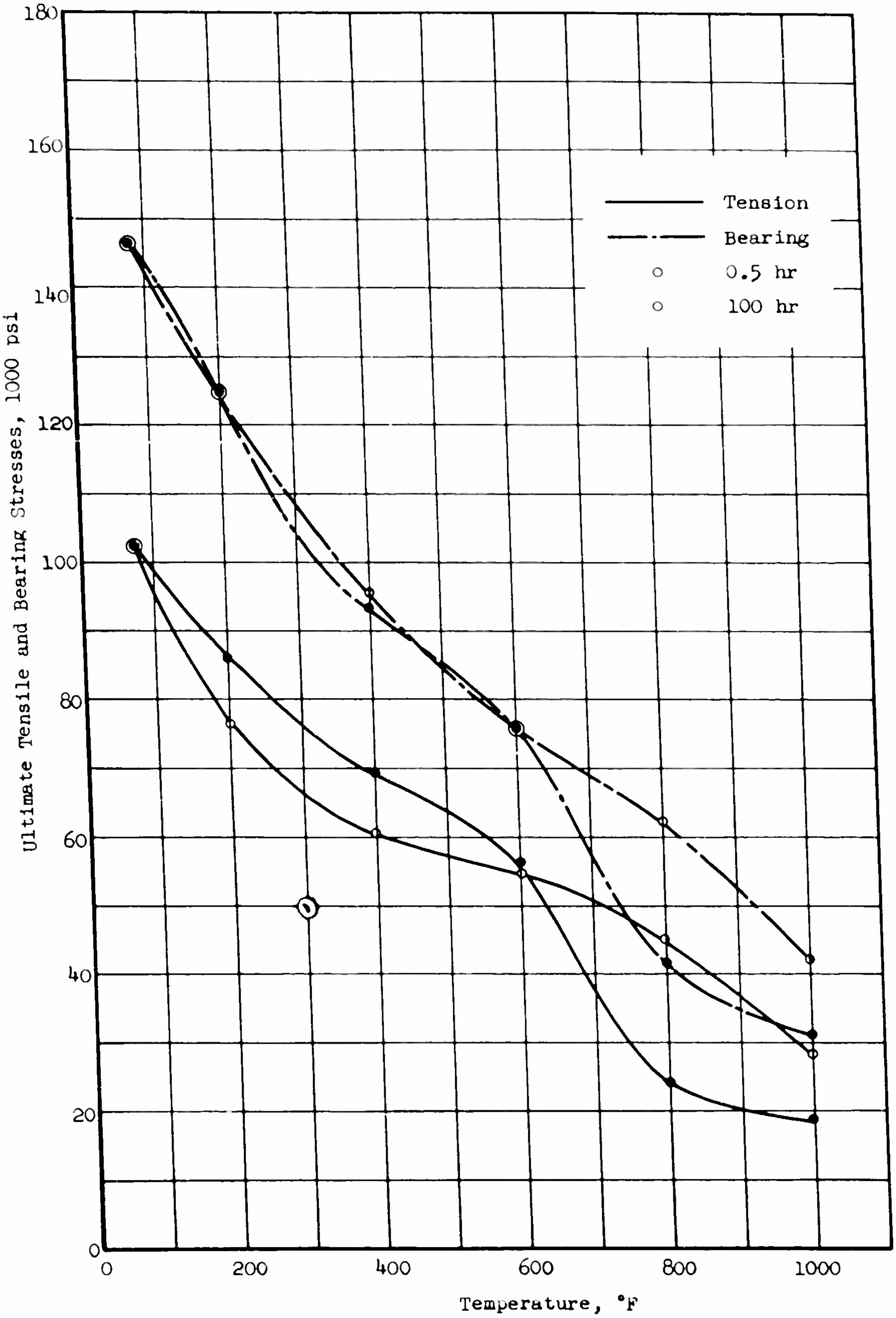

Fig. 23 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND BEARING STRENGTHS OF COLD ROLLED TITANIUM

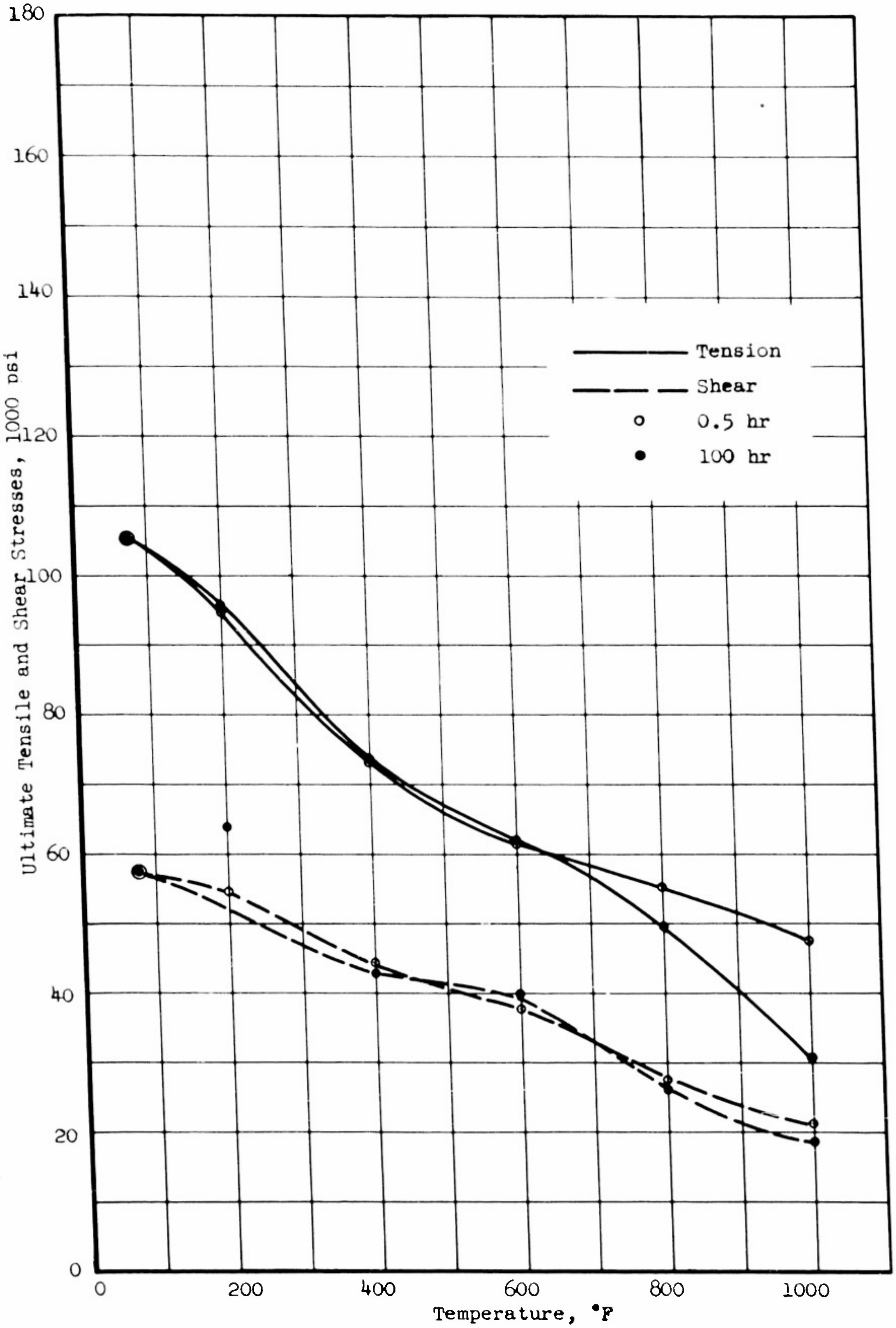

Fig. 24 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND SHEAR STRENGTHS OF COLD ROLLED TITANIUM

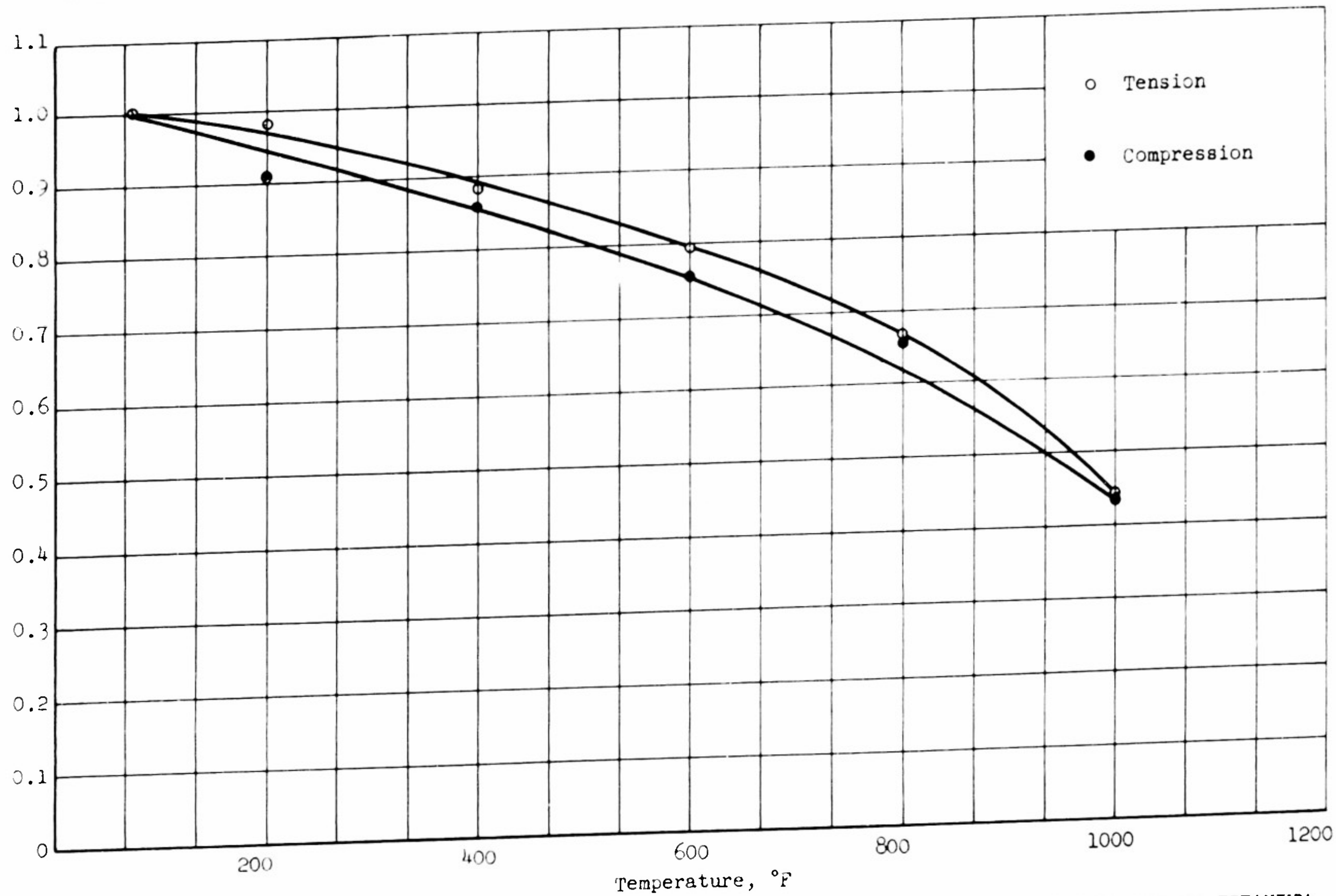

Fig. 25 EFFECT OF TEMPERATURE ON THE TENSILE AND COMPRESSIVE MODULI OF ELASTICITY OF COLD ROLLED TITANIUM

Exposure time appears to be far less important than temperature for the two periods investigated. The 0.5 hour and 100-hour curves of nearly every property intersect one or more times in erratic fashion.

According to Fig. 25, which illustrates the variation of the tensile and compressive moduli of elasticity as a function of temperature, both moduli decrease steadily with increasing temperature. The average tensile modulus is slightly higher percentagewise than the compressive at all temperatures. Actually, the differences between the two moduli are greater than those indicated by the curves, because at room temperature the tensile modulus is higher than the compressive.

Examination of the 200°F data from individual tests of cold rolled titanium sheet material, which appears in Table B-16 (Appendix B), reveals that for many properties and conditions, test results were widely scattered. It was often necessary to conduct check tests to determine meaningful averages. In employing experimental data to establish design information, it is important to be aware of test results which are substantially below average. The tables of results of individual tests should be carefully reviewed to avoid overemphasizing the significance of average value data.

H. Results of Mechanical Properties Tests of Annealed Titanium at 200°F

The average values of properties of annealed titanium sheet material at 200°F are presented in Table 6. As was the case with the cold rolled titanium, these results were used in conjunction with data obtained in the first phase of the program to construct graphs which illustrate the relationships between various mechanical properties and temperature. The graphs are shown in Figs. 26 to 29. Two curves appear on each graph, one for each of

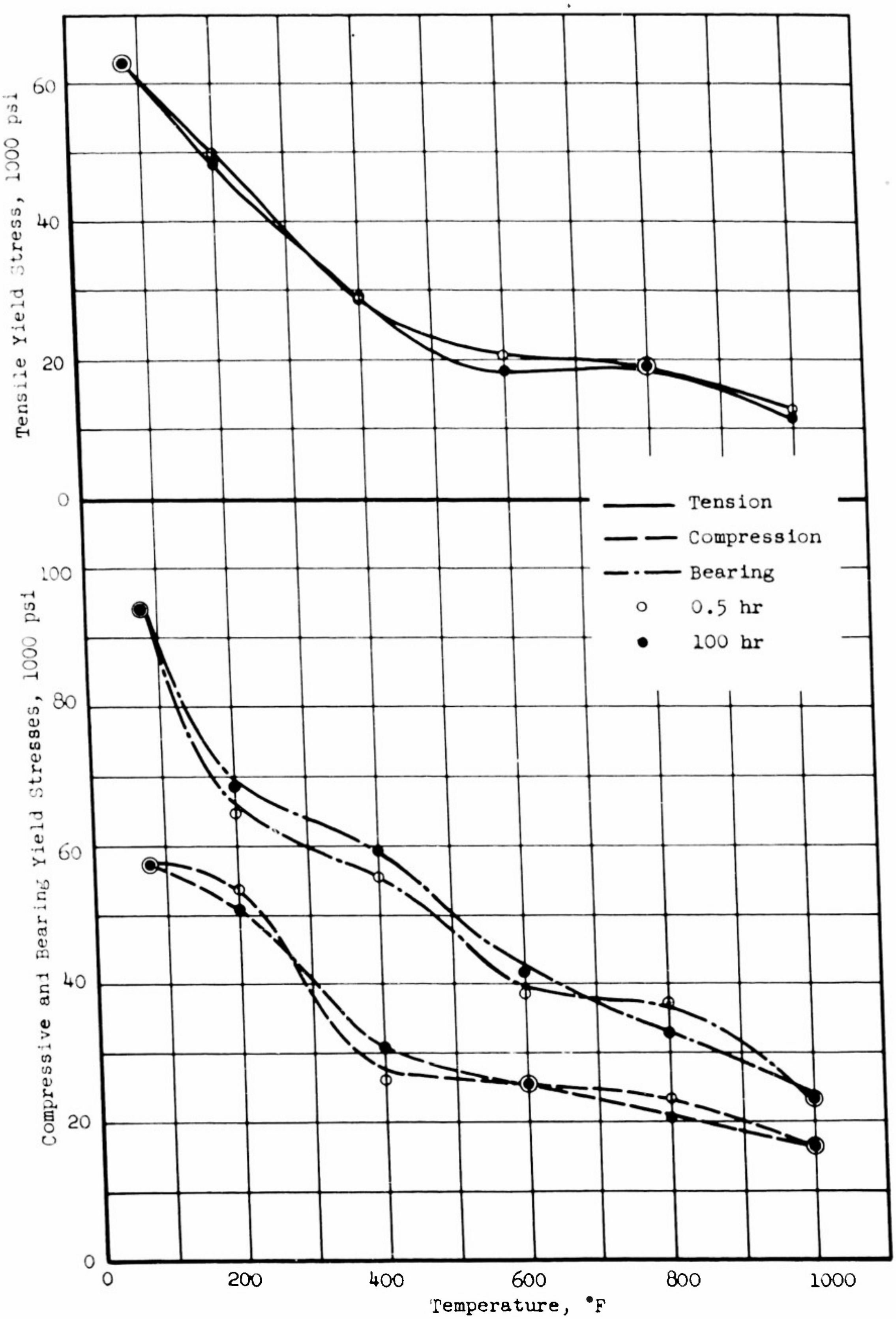

Fig. 26 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON TENSILE, COMPRESSIVE, AND BEARING YIELD STRENGTHS OF ANNEALED TITANIUM

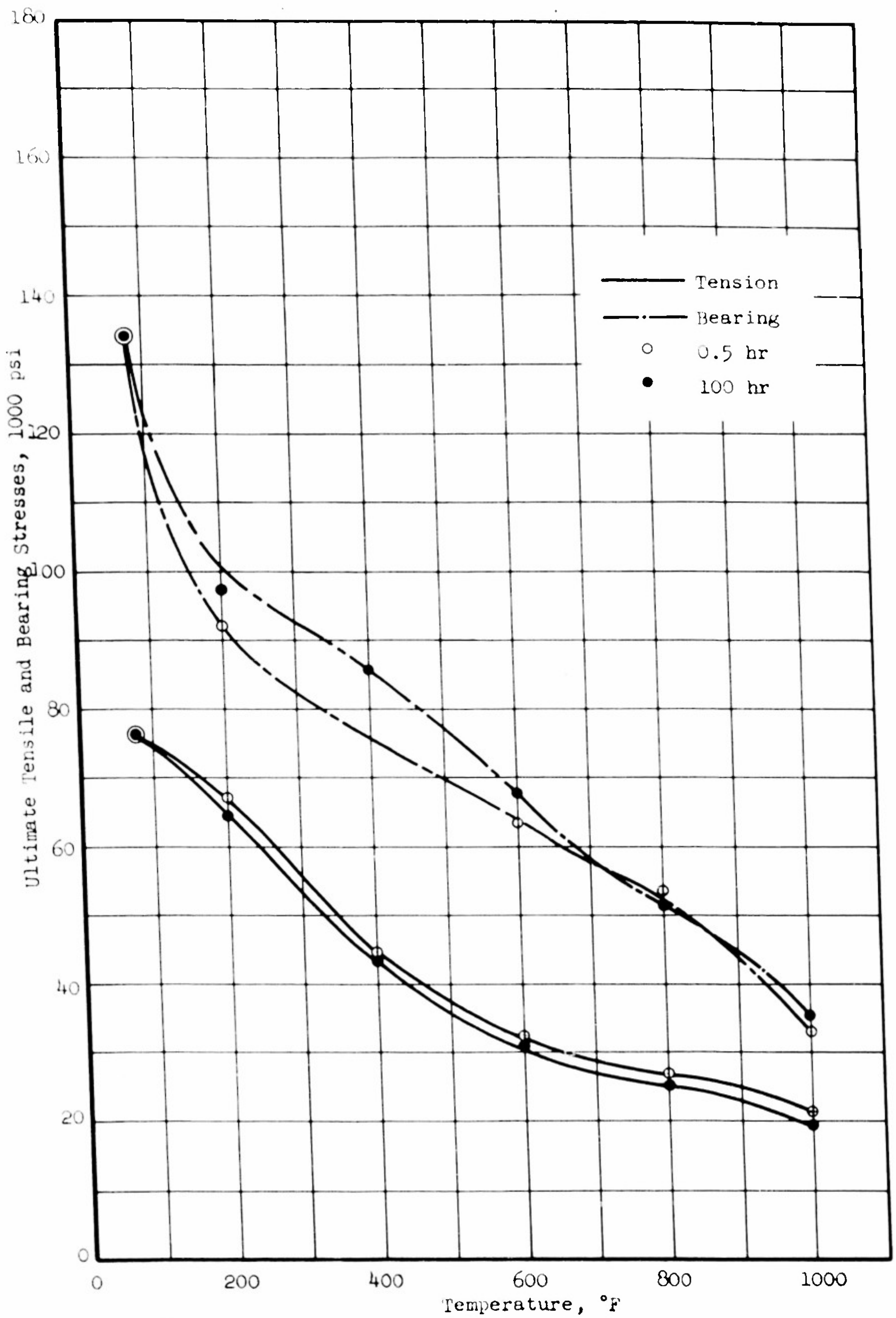

Fig. 27 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND BEARING STRENGTHS OF ANNEALED TITANIUM

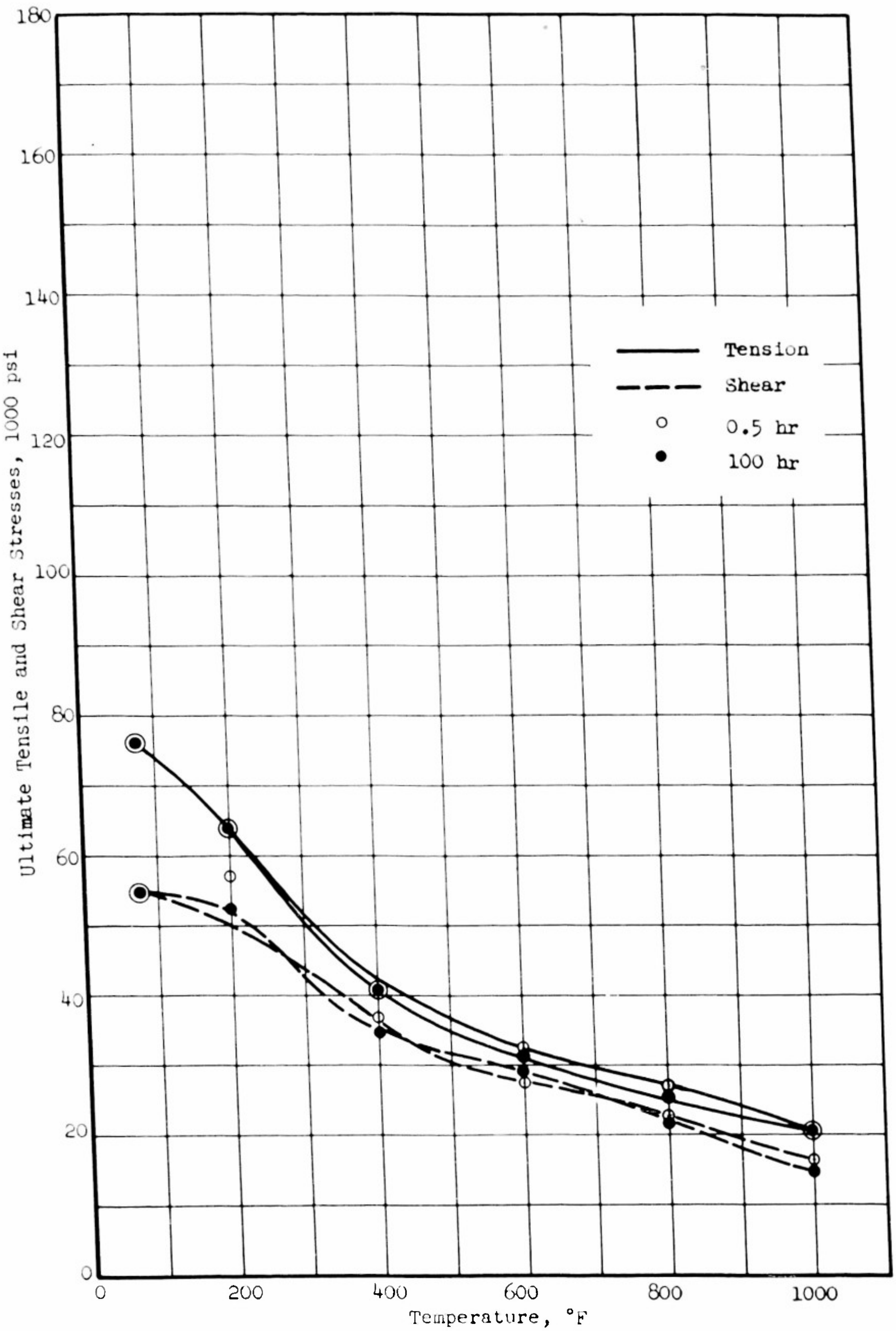

Fig. 28 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND SHEAR STRENGTHS OF ANNEALED TITANIUM

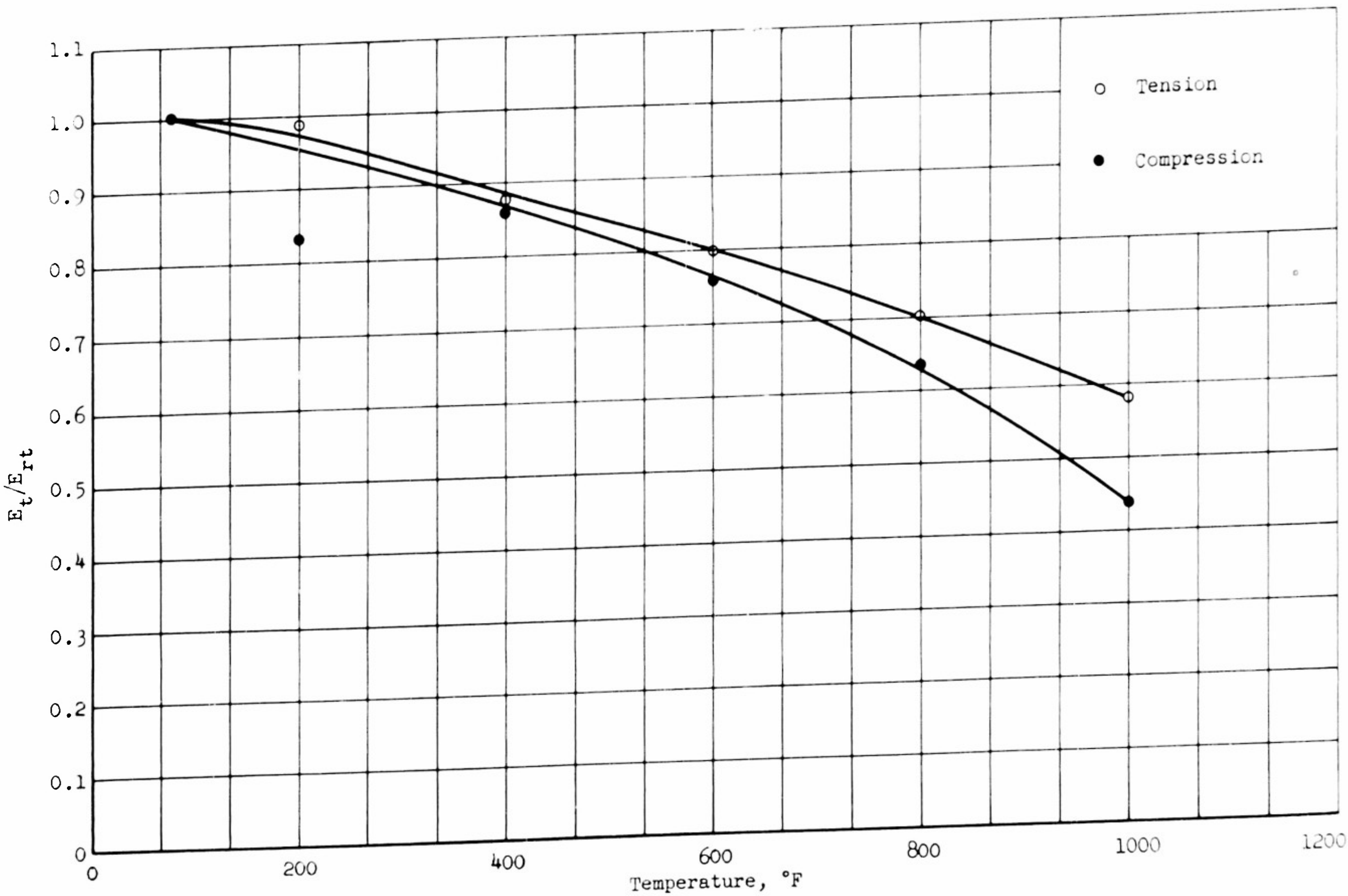

Fig. 29 **EFFECT OF TEMPERATURE ON THE TENSILE AND COMPRESSIVE MODULI OF ELASTICITY OF ANNEALED TITANIUM**

the two exposure conditions under which tests were performed, 0.5 and 100 hours. Because they include 200°F data, the figures presented in this report supersede those appearing in Part 1 of AF Technical Report 6517.

In general, the properties of annealed titanium exhibit progressive decline as temperatures increase. However, the percentile decreases suffered by the various properties differ widely in each temperature interval. The properties appear to correlate very poorly in this respect.

Temperature exerts far greater influence on annealed titanium sheet material than does exposure time, at least for the two periods considered. The 0.5- and 100-hour curves in most cases follow the same trend throughout the full range of test temperature, but they intersect chaotically, which indicates that exposure for a period of 100 hours produces no consistent effect.

Curves illustrating the manner in which the tensile and compressive moduli of elasticity vary as functions of temperature are shown in Fig. 29. Both moduli decrease steadily with increasing temperature. Although the tensile modulus is greater percentagewise than the compressive over the range of temperatures at which tests were performed, the actual values of the two moduli were almost the same, because at room temperature the compressive modulus was larger than the tensile.

Note that the 200°F compressive modulus point lies well away from the curve. The data from individual tests presented in Table B-17 shows that the results of tests of annealed titanium sheet were widely scattered for many conditions, including this one. Four additional compressive tests were needed to obtain representative values for compressive yield strength and the compressive modulus of elasticity. Values of the latter property

ranged between 9.3 and 19.7; the extreme values were not included in the reported averages, of course. There is no apparent reason for the extreme disparity between the modulus determined by the 200°F experiments and the value indicated by the curve.

Because of the wide variation in results observed under certain test conditions, design values must be formulated with caution. It appears that the properties of the titanium material from which test specimens were fabricated were not the same at all areas of the sheet.

I. Effect of Temperature and Exposure Time on RC-130-A Titanium Alloy

The average values of mechanical properties of RC-130-A titanium alloy sheet material are presented in Table 7. On Figs. 30 through 32, the properties are plotted as functions of exposure time for various temperatures. The manner in which the tensile and compressive moduli of elasticity vary with temperature is illustrated by Fig. 33. Data from tests conducted at 800°F are not included on the graphs because results for the 1000-hour exposure condition were not available early enough for presentation in the report. These data, together with the results of tests performed at 1000°F for all exposure periods, will appear in the reports for the next phase of the program.

The performance of the RC-130-A titanium alloy sheet material tested in the present phase of the program was extremely erratic. According to the sponsor, the sheet from which test specimens were fabricated was drawn from one of the first lots of this material. Processing techniques had not been fully developed at the time the sheet was rolled. They have been much improved since that time. The RC-130-A titanium sheet currently being produced

Table 7

MECHANICAL PROPERTIES OF RC-130-A TITANIUM ALLOY FOR VARIOUS TEMPERATURES AND EXPOSURE TIMES EXPRESSED AS A PERCENTAGE OF ROOM TEMPERATURE VALUES

Temp °F	Exposure Time, hr	Yield Strength Tensile	Yield Strength Compressive	Yield Strength Bearing	Ultimate Strength Tensile	Ultimate Strength Bearing	Modulus of Elasticity Tensile	Modulus of Elasticity Compressive	Ultimate Strength, 3/16 in. Tensile	Ultimate Strength, 3/16 in. Shear
78		128,800 psi	139,800 psi	153,700 psi	133,300 psi	202,500 psi	18.0×10^6 psi	17.0×17^6 psi	140,300 psi	101,400 psi
300	0.5	77.1	77.0	96.7	88.9	92.0	96.6	91.7	82.0	88.0
	100	73.8	64.8	88.0	87.3	85.5	103.3	90.6	82.8	87.5
	1000	77.5	76.7	90.6	88.9	87.0	95.5	95.9	83.2	88.6
500	0.5	58.1	61.0	83.3	78.1	80.8	64.5	83.0	76.0	80.8
	100	71.6	65.0	90.1	85.0	83.2	94.5	86.5	81.0	79.6
	1000	59.8	60.6	88.1	80.7	83.2	83.9	80.0	79.0	79.2
600	0.5	63.3	67.0	76.5	77.7	74.8	75.6	80.5	72.0	76.4
	100	68.5	63.7	67.3	80.5	64.4	86.6	75.3	79.6	74.6
	1000	59.9	64.1	83.7	76.9	79.4	88.3	73.5	98.0	76.9
800	0.5	54.6	61.4	75.8	71.3	71.7	65.0	61.2	65.2	69.4
	100	55.1	46.6	75.7	69.8	71.2	65.0	77.6	74.6	70.4
	1000*	---	---	---	---	---	---	---	---	---

*Data for this condition will be presented in the reports for the next supplement of the program.

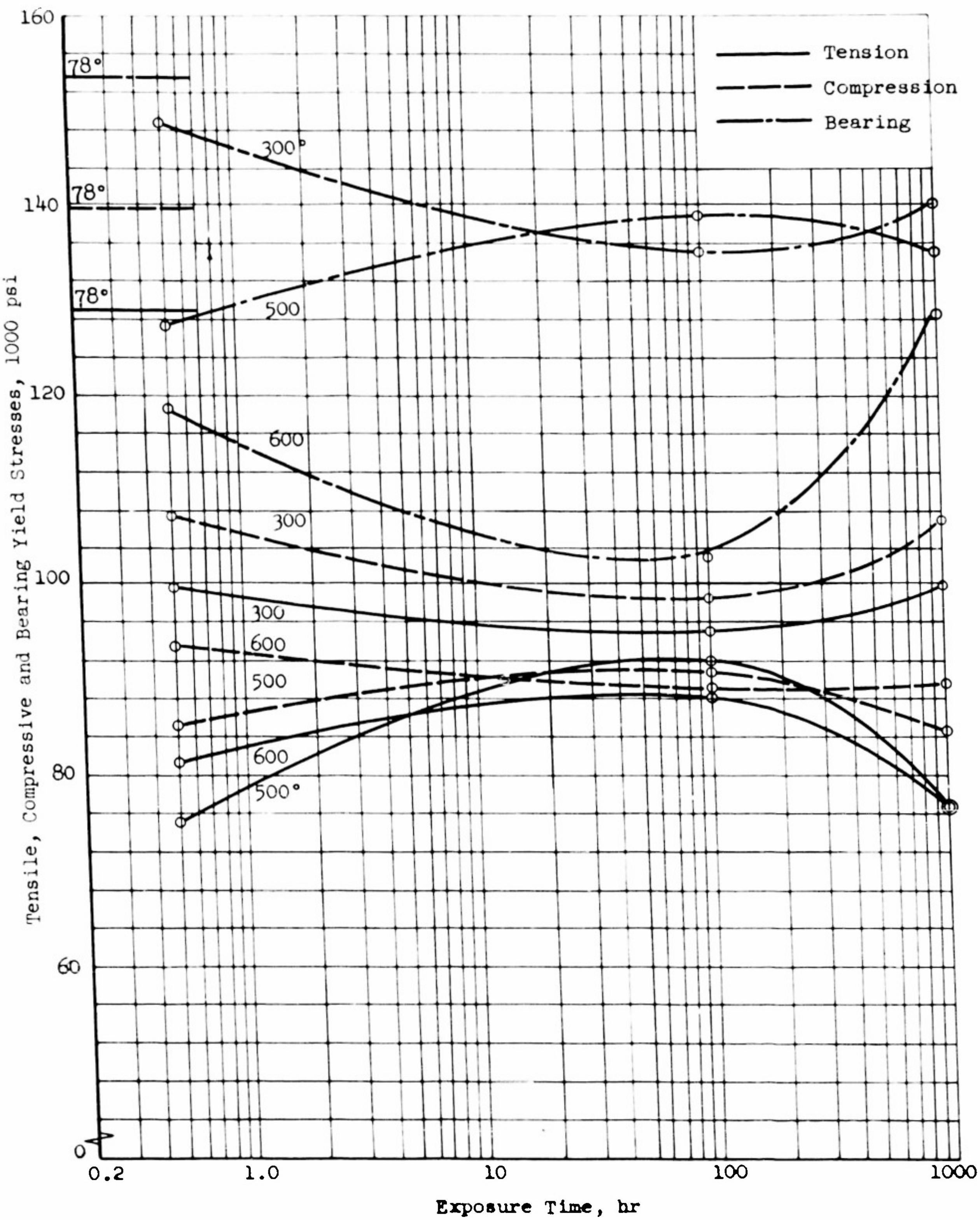

Fig. 30 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON TENSILE, COMPRESSIVE, AND BEARING YIELD STRENGTHS OF RC-130-A TITANIUM ALLOY

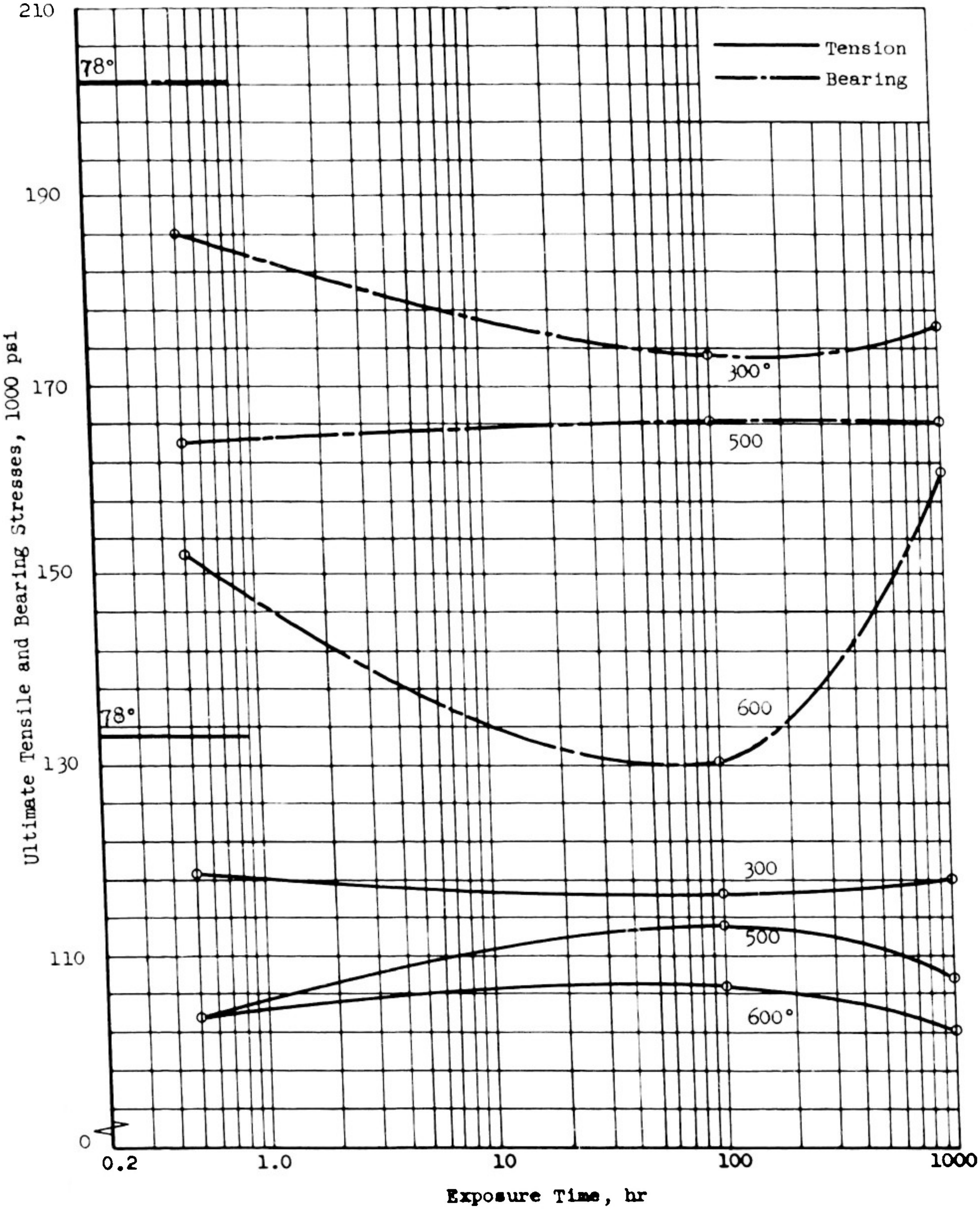

Fig. 31 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND BEARING STRENGTHS OF RC-130-A TITANIUM ALLOY

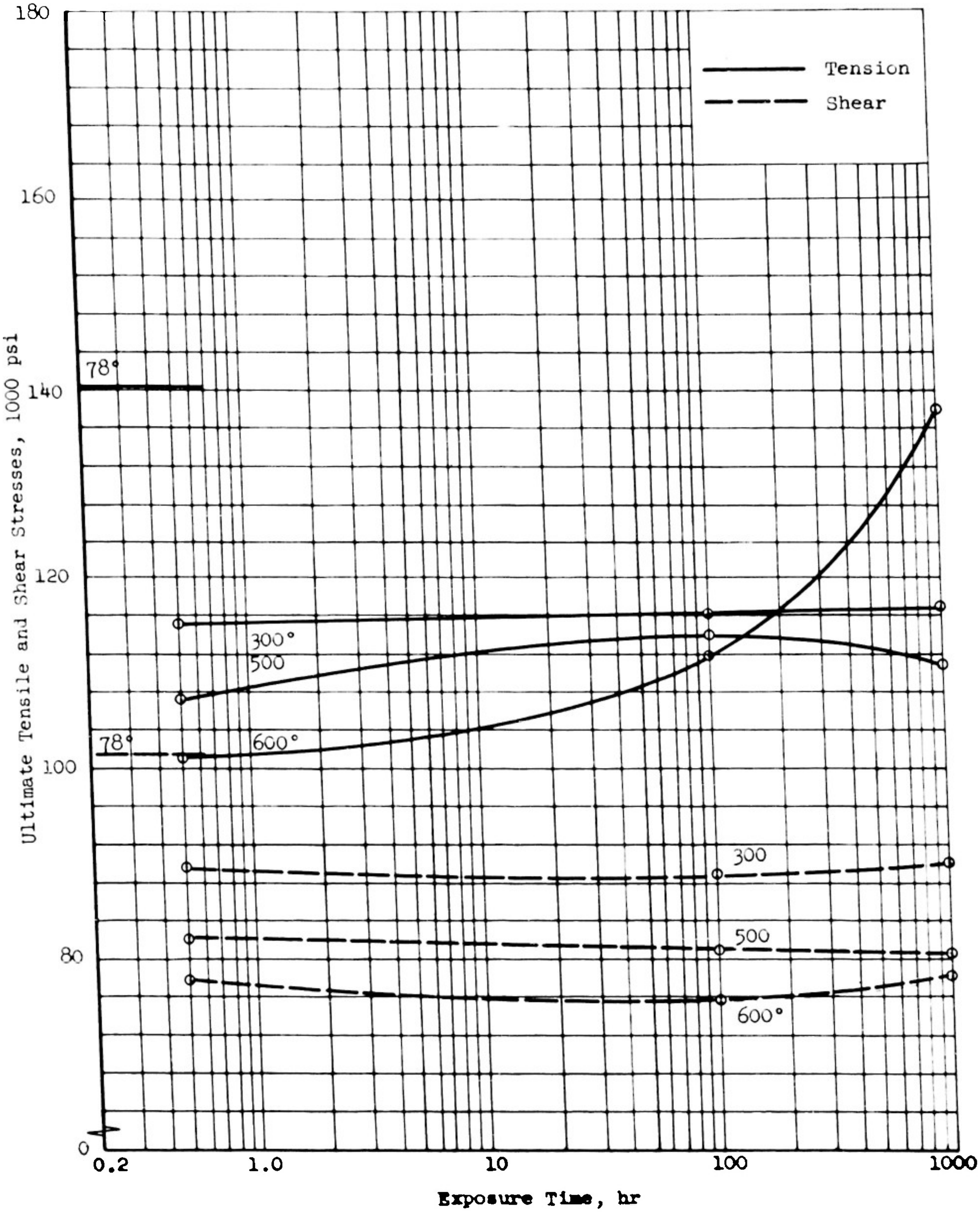

Fig. 32 EFFECT OF TEMPERATURE AND EXPOSURE TIME ON ULTIMATE TENSILE AND SHEAR STRENGTHS OF RC-130-A TITANIUM ALLOY

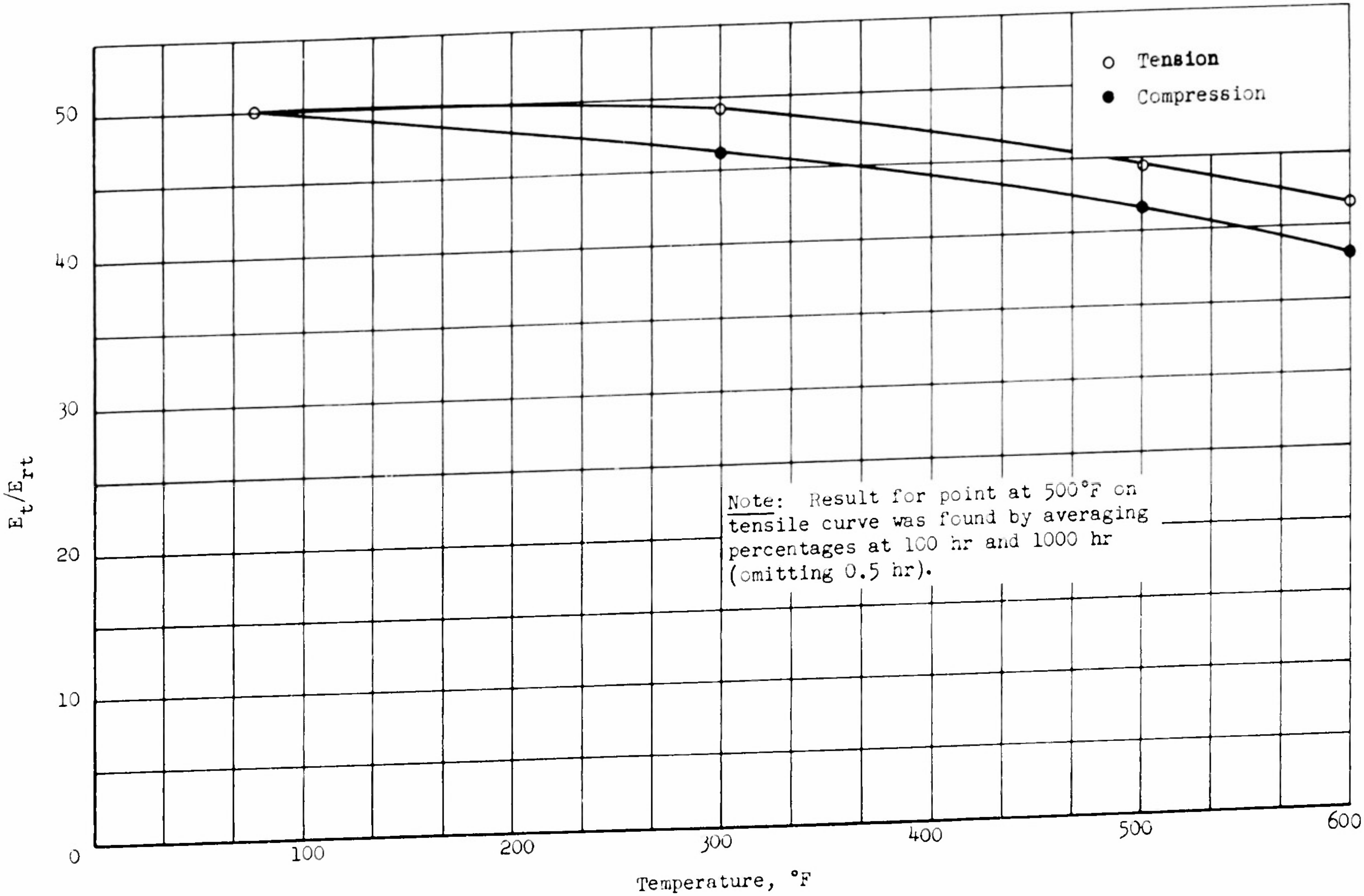

Fig. 33 EFFECT OF TEMPERATURE ON THE TENSILE AND COMPRESSIVE MODULI OF ELASTICITY OF RC-130-A TITANIUM ALLOY

is reported to be quite satisfactory from the standpoint of uniformity of properties.[1] For this reason, the data presented in this section is of questionable applicability. In any event, no conclusions should be drawn until the data from individual tests, which is presented in Tables B-18 through B-22, has been thoroughly reviewed.

Partly because the experimental results were erratic and partly because tests were performed for only three exposure periods, the effect of exposure time on the mechanical properties of RC-130-A titanium is difficult to evaluate. However, the properties do show consistency in a few particulars. Observe from the curves that at 300°F, all properties except the ultimate strength of 3/16-inch material are lower for the 100-hour exposure condition than for either the 0.5-hour or the 1000-hour condition. At 500°F, the reverse is true; all properties except ultimate shear strength are higher for the 100-hour condition than for the other exposure conditions. No consistent behavior can be noticed from the 600°F curves. It is risky to generalize on the basis of data of this kind, but indications are that exposure time exerts no gross influence on the properties of RC-130-A titanium in the temperature range from 78° to 600°F.

The manner in which the properties of this material are affected by temperature is less obscure. At 300°F all properties declined from their room temperature values; they became further reduced upon exposure at 500°F. However, at 600°F the tensile and compressive yield strengths increased slightly for the 0.5- and 1000-hour exposure conditions, and the bearing yield strength returned almost to its room temperature value after

[1] It is planned to test material from a more recent test in the near future.

the material had been exposed for 1000 hours at this temperature. For all other conditions, exposure at 600°F caused a further reduction in mechanical properties. The tabulated data indicates that at 800°F a general decline again took place. There was one exception, however; for the 100-hour exposure condition, the ultimate bearing strength exhibited a significant increase.

The tensile and compressive moduli of elasticity of RC-130-A titanium are shown as functions of temperature in Fig. 33. Almost alone among the properties of this material, the average moduli display a distinct and consistent behavior. Both decline progressively as temperatures increase. The compressive modulus decreases more percentagewise than the tensile, at least in the range from 78° to 600°F. The actual differences between the two average moduli are greater than those indicated by the curves because the tensile modulus is slightly higher at room temperature than the compressive. It should not be construed from the smoothness and regularity of the modulus curves that the modulus data from individual tests were comparably consistent. In many cases, widely divergent values were recorded. To provide an example of the disparity which was observed in the results for some conditions, one stress-strain curve with an unusually high modulus has been included in Fig. C-56.

In the sections describing the results obtained from tests of cold rolled and annealed titanium, it was remarked that the average value data for those materials should be interpreted with caution. This admonition applies with special emphasis to the RC-130-A data. Because of the wide disparity between results obtained under certain conditions in the tests originally scheduled, it became necessary to perform a large number of check

tests. In most instances, the results of the check tests furnished enough information to establish reasonably reliable average values, and hence to allow removal of excessively high and low values from the average value computations. However, in a few cases, the check tests yielded results both higher and lower than any of the values previously obtained, which were themselves widely scattered. Needless to say, averages obtained under such circumstances are gravely questionable.

It is recommended that the results of individual tests, which are tabulated in Appendix B, be reviewed very carefully. For some conditions grossly sub-standard values of certain properties were recorded. Apparently the sheet from which test specimens were fabricated had a number of weak areas. Hence, the fact that data was closely reproducible for certain properties and conditions does not indicate that the recorded averages are reliable for those properties and conditions. Stated in another way, the existence of wide scatter in the data for a few properties and conditions compromises the validity of the results obtained for other properties and conditions.

IX. COMPARISON OF PROPERTIES AT VARIOUS TEST CONDITIONS

In Tables 2, 3, 4, 6, and 7, the elevated temperature properties of the materials tested in the current phase of the program are expressed as percentages of room temperature values. This manner of presentation facilitates comparison of the changes which take place in different properties at each temperature and exposure condition. If simple relationships exist between the properties, they will be disclosed by tabulations of this kind.

The tables have been examined to determine whether the various elevated temperature properties are related in consistent fashion. In particular,

the tensile data were compared with data on compressive, bearing, and shear, in the hope that means could be discovered of predicting the latter properties from a knowledge of tensile data at elevated temperatures and compressive, bearing, and shear properties at room temperature.

Dorn (Reference 1) found that the relationship

$$CYS_{t_1} = CYS_{RT}\ (TYS_{t_1}/TYS_{RT})$$

agreed satisfactorily with the data from tests performed under rather specialized conditions at temperature up to 300°F. In this equation,

CYS_{t_1} = Compressive yield strength of 0.125-inch bare sheet for temperature t_1 at any time, cross grain

CYS_{RT} = Compressive yield strength of 0.125-inch bare sheet at room temperature

TYS_{t_1} = Tensile yield strength of 0.040-inch clad sheet for temperature t_1 at any time, cross grain

TYS_{RT} = Tensile yield strength of 0.040-inch clad sheet at room temperature.

The above equation simply states that the compressive yield strength changes in the same proportion as the tensile yield strength. If this relationship were postulated to hold for other properties as well, its generalized formulations would be written as follows:

$$\frac{TYS_{t_1}}{TYS_{RT}} = \frac{CYS_{t_1}}{CYS_{RT}} = \frac{BYS_{t_1}}{BYS_{RT}}$$

$$\frac{UTS_{t_1}}{UTS_{RT}} = \frac{UBS_{t_1}}{UBS_{RT}} = \frac{USS_{t_1}}{USS_{RT}}$$

$$\frac{E_{(tensile)t_1}}{E_{(tensile)RT}} = \frac{E_{(compressive)t_1}}{E_{(compressive)RT}} .$$

The tabulated average value data indicates that these equations are not valid, in general. For the aluminum materials, they appear to be adequate for a number of conditions at temperatures up to 300°F. However, for the other materials, they do not agree well with the data, even at relatively low temperatures. It has been concluded from examination of the test results in this and previous phases of the program that the relationships between the properties are very complex, and that elevated temperature values cannot be predicted accurately by using room temperature results as a standard. This should not be surprising, because the states of stress and the mechanisms of failure are not the same in the various tests; therefore, it is quite unlikely that the properties are related in a simple way.

X. GENERAL CONCLUSIONS

Specific conclusions applicable to particular materials were discussed previously in the sections summarizing the test results. The remarks of this section apply to all of the materials tested, unless exceptions are cited expressly.

1. In most cases, the tensile, compressive, and bearing yield strengths are affected in the same general fashion by exposure to elevated temperatures. These properties decrease as temperatures increase. At temperatures in excess of 200°F, they also tend to diminish as exposure times are increased, except in the case of the titanium materials, for which no distinct pattern of behavior was apparent.

2. The ultimate tensile, bearing, and shear strengths respond similarly upon exposure to elevated temperatures. Like the yield strengths, they

diminish with increasing temperature, and, the titanium materials excepted, they also diminish with increased time of exposure when temperatures are over 200°F.

3. Exposure at elevated temperatures affects the yield strength and ultimate strength of a given material in the same way.

4. The tensile and compressive moduli of elasticity decrease as the temperature increases, but usually not at the same rate. The rates do not differ greatly, however.

5. Exposure time does not appear to affect the moduli of elasticity in a consistent manner.

6. While the physical properties of the aluminum materials can be estimated for some conditions within a limited temperature range by calculations based on the complete tensile data and knowledge of the other properties at room temperature, the test results indicate that, in general, elevated temperature mechanical properties cannot be predicted by any simple method.

DEMiller/edit/kf

BIBLIOGRAPHY

1. Flanigan, A. E., Tedson, L. F., and Dorn, J. E. "Compressive Properties of Aluminum Alloy Sheet at Elevated Temperatures." Proceedings ASTM, Vol. 46, pp. 951-970. 1946.

2. Flanigan, A. E., Tedson, L. F., and Dorn, J. E. "Bearing Properties of 24S-T Sheet and Shear Strength of 24S-T Rivets at Elevated Temperatures." Transactions ASTM, Vol. 38, pp. 780-807. 1947.

3. Test Methods of the Materials Laboratory, NDRC Reports, Serial No. M-566, Vols. I and II, Engineering Division, Air Technical Service Command.

4. Short-Time Elevated-Temperature Tensile Tests of Metallic Materials. ASTM Designation E21-43. 1943.

5. Strength of Metal Aircraft Elements. Munitions Board Aircraft Committee Document ANC-5a, May, 1949.

6. Dix, E. H., Jr., "New Development in High Strength Aluminum Alloy Products." Transactions American Society of Metals, Vol. 35, pp. 130-148. 1945.

APPENDIX A

TEMPERATURE DISTRIBUTION THROUGHOUT TEST SPECIMENS

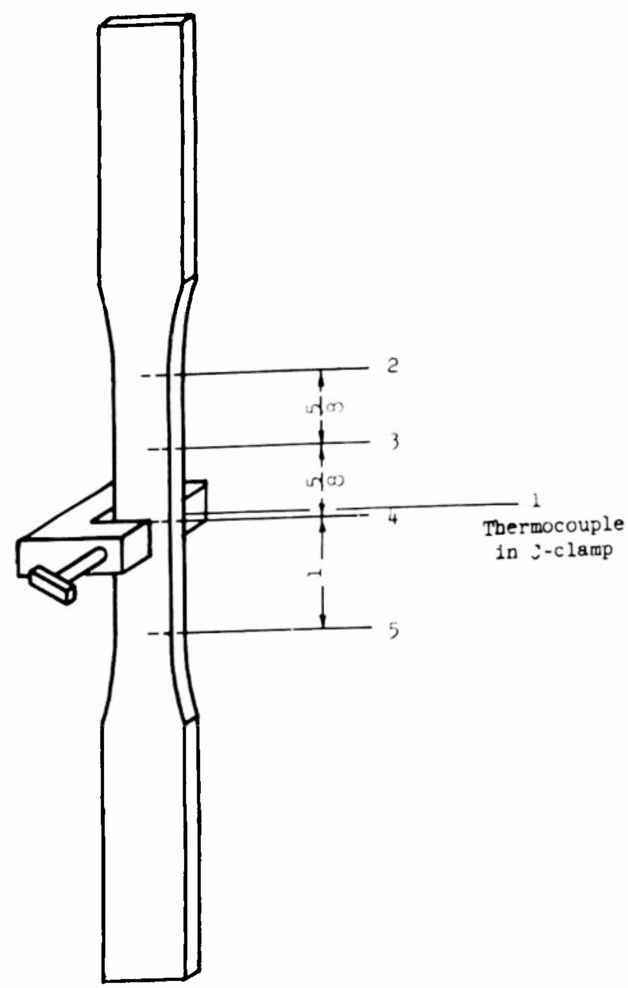

Fig. A-1 LOCATION OF THERMOCOUPLES IN TENSILE SPECIMEN

Table A-1

TEMPERATURE DISTRIBUTION IN A TENSILE TEST SPECIMEN

Test Temperature °F	Temperature at Thermocouples, °F				
	1	2	3	4	5
212	206	215	212	214	205
300	298	311	300	298	280
400	395	408	405	398	378
500	495	500	500	492	475
600	600	610	605	600	565
700	715	705	705	694	655
800	810	816	808	789	745
1000	1010	1018	1015	1000	972

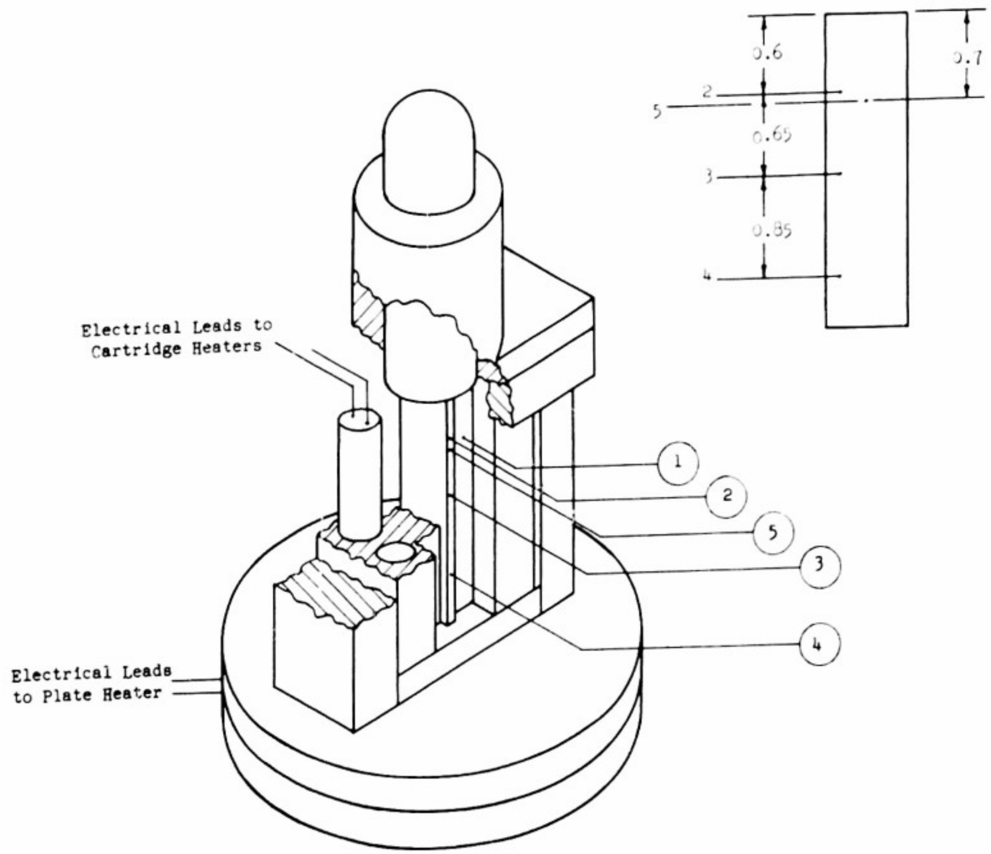

Fig. A-2 COMPRESSIVE TEST FIXTURE AND SPECIMEN WITH THERMOCOUPLES

Table A-2

TEMPERATURE DISTRIBUTION IN A
COMPRESSIVE SPECIMEN SET IN THE TEST FIXTURE

Test Temperature °F	Temperature at Thermocouples, °F 1	2	3	4	5
212	212	210	214	209	212
300	300	303	305	300	302
400	400	400	402	402	402
500	500	500	498	502	500
600	600	597	603	590	597
700	700	698	70[illegible]	695	698
800	800	796	800	795	798
1000	1000	985	1000	1015	990

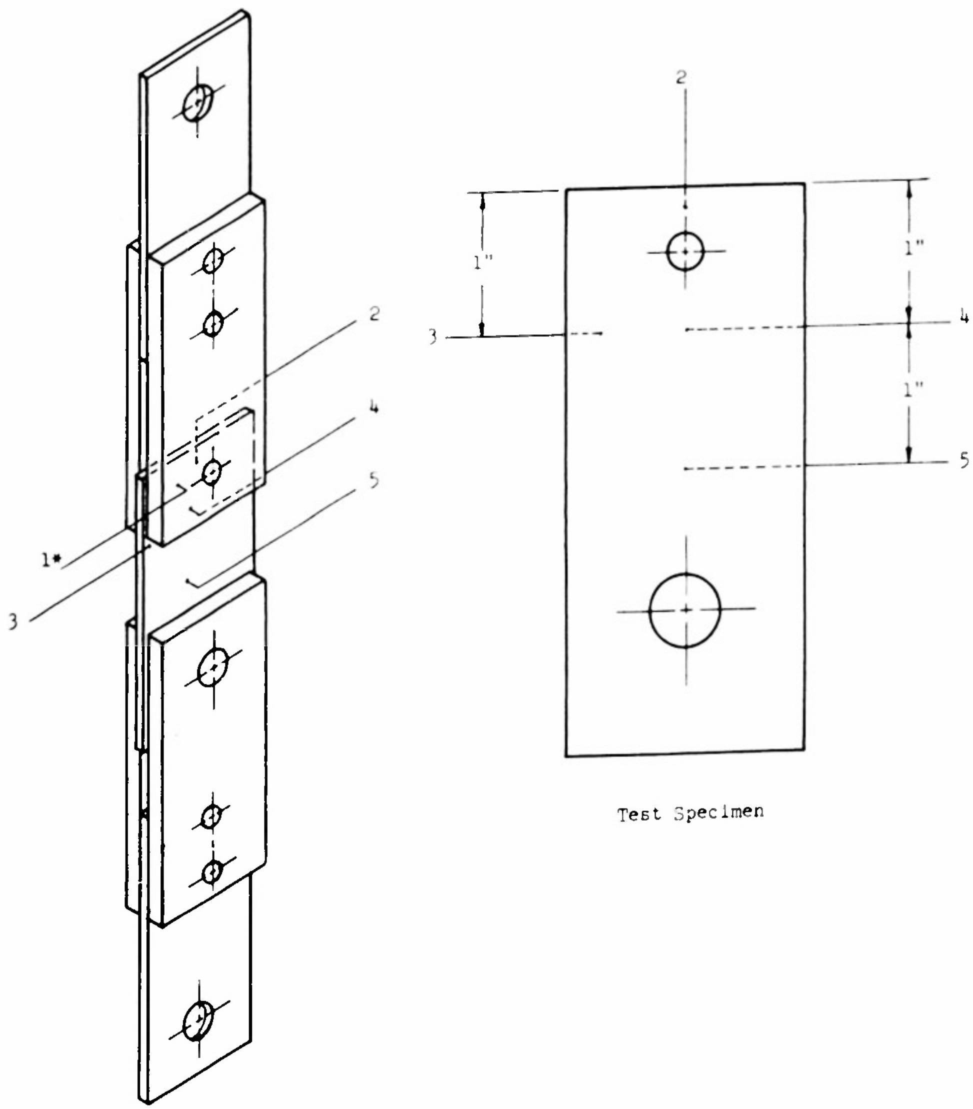

Fig. A-3 BEARING TEST FIXTURE AND SPECIMEN WITH THERMOCOUPLES

Table A-3

TEMPERATURE DISTRIBUTION IN A BEARING SPECIMEN SET IN THE TEST FIXTURE

Test Temperature °F	Temperature at Thermocouples, °F 1*	2	3	4	5
212	212	212	210	210	206
300	313	300	298	299	295
400	412	400	396	397	392
500	510	500	496	497	490
600	610	600	598	599	595
700	720	700	695	698	685
800	810	800	790	790	780
1000	1010	1000	999	999	993

*Thermocouple located in test fixture.

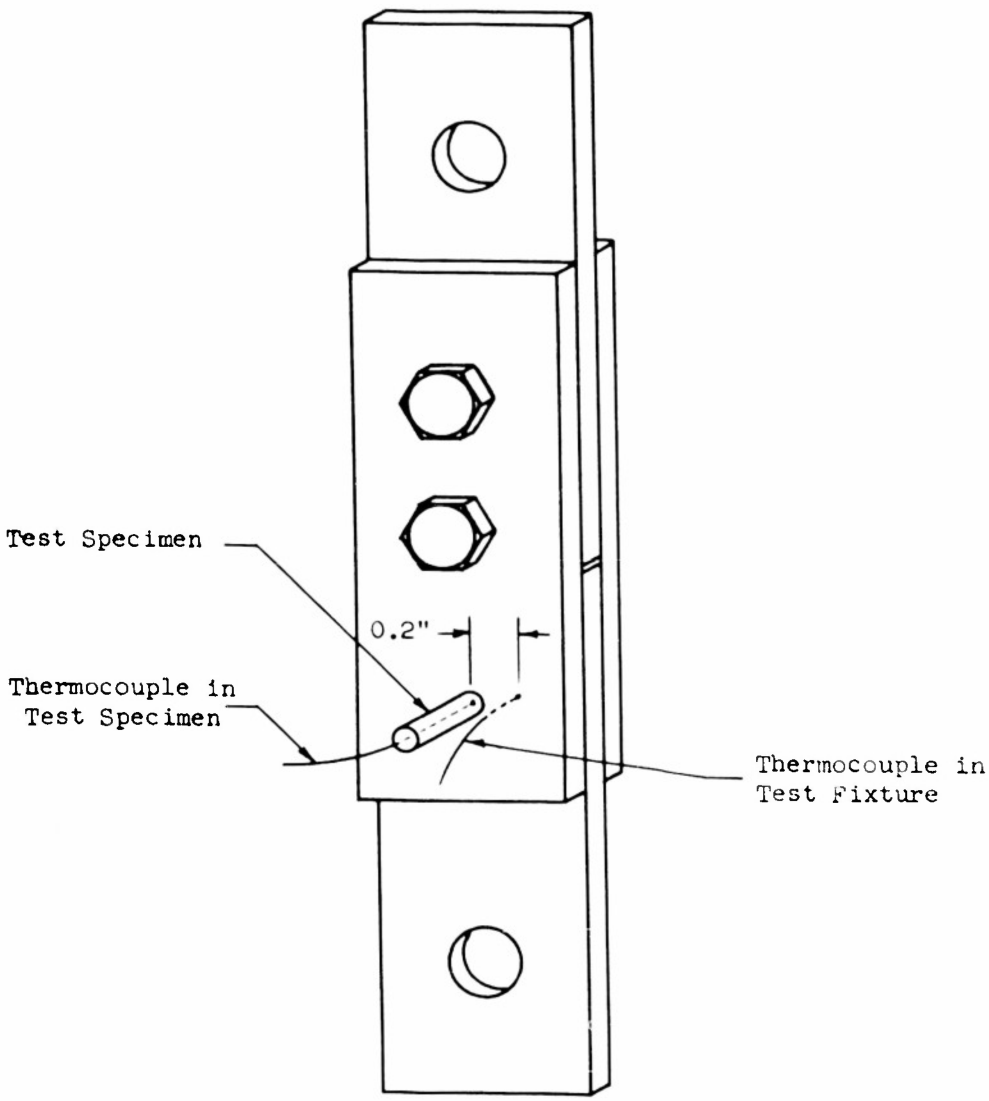

Fig. A-4 LOCATION OF THERMOCOUPLES IN SHEAR SPECIMEN AND TEST FIXTURE

APPENDIX B

TABLES OF TEST RESULTS

Table B-1

RESULTS OF TENSILE TESTS OF 14S-T6 CLAD ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time, hr	75°F Tensile Yield Stress, psi	75°F Ultimate Tensile Stress, psi	75°F Modulus of Elasticity, 10^6 psi	200°F Tensile Yield Stress, psi	200°F Ultimate Tensile Stress, psi	200°F Modulus of Elasticity, 10^6 psi	300°F Tensile Yield Stress, psi	300°F Ultimate Tensile Stress, psi	300°F Modulus of Elasticity, 10^6 psi	400°F Tensile Yield Stress, psi	400°F Ultimate Tensile Stress, psi	400°F Modulus of Elasticity, 10^6 psi	500°F Tensile Yield Stress, psi	500°F Ultimate Tensile Stress, psi	500°F Modulus of Elasticity, 10^6 psi	600°F Tensile Yield Stress, psi	600°F Ultimate Tensile Stress, psi	600°F Modulus of Elasticity, 10^6 psi
0.5	58,000	63,000	12.5[a]		60,000	9.7	50,000	55,700	10.5	35,500	45,100	10.0	15,500	16,000	8.5	9,600	11,000	8.6
	56,100	64,000	10.7	56,000	61,300	12.5[a]	50,000	55,600	11.2	40,000	45,100	12.2[a]	15,200	15,800	7.0	11,700	11,900	8.3
		63,500		52,500	57,900	11.5				-	-	10.4				9,600	10,800	5.8[a]
					57,300	9.7												
Ave.				54,200	59,200	10.3	50,000	55,650	10.8	37,700	45,100	10.2	15,300	15,900	7.7	10,300	11,200	8.4
	58,000	64,000	11.5[a]	53,000	60,000	10.5	48,000	54,200	9.5	37,500	40,900	10.5	Reliable data		8.0	8,600	9,200	9.0[a]
	56,800	61,000	10.4	54,000	59,000	10.6	51,500	55,200	9.0	38,000	42,000	10.5	were not		7.6	8,800	9,300	4.1[a]
	57,500	64,000	10.5	53,000[a]	58,500	11.0							obtained		8.5	8,700	9,100	5.2[a]
	-	-	10.7										for this					
													condition.					
Ave.	57,300	63,200	10.6	53,500	59,400	10.5	49,700	54,700	9.2	37,800	41,500	10.5			8.0	8,600	9,200	
10				54,000	59,700	10.0	48,000	54,200	12.0[a]	26,000	29,000	9.5	11,300	12,200	12.7[a]	7,300	8,200	7.9
				53,000	59,300	10.2	50,000	55,000	12.5[a]	26,500	29,500	11.3	11,100	11,800	8.9	8,000	8,600	8.8
							47,000	53,300	9.5				11,600	15,600[a]	6.4	7,300	8,400	6.4
							47,000	55,300	9.7									
Ave.				53,500	59,200	10.1	48,000	54,200	9.5	26,200	29,200	10.4	11,300	12,000	7.6[b]	7,900	8,400	7.7
100				54,000	61,500	10.3	50,000	55,000	9.0	19,000	21,800	10.3	10,200	11,000	10.2	6,900	7,200	6.6
				57,500	62,300	10.9	48,000	54,600	11.5	19,000	22,000	9.5	10,200	11,000	12.8[a]	6,700	7,500	6.5
							-	52,200	11.7				10,200	11,000	8.0	6,800	8,400	6.9
							-	-	9.6							6,960	7,900	7.0
																6,960	8,000	8.3[a]
Ave.				55,700	61,900	10.2	49,000	53,900	10.5[b]	19,000	21,900	9.9	10,200	11,000	9.1[b]	6,860	7,800	6.85
1000				57,500	62,700	10.0	40,700	47,000	14.0[a]	15,000	16,800	10.0	9,500	11,500	8.1	6,900	8,100	8.2
				59,000	61,600	11.0	-	47,700	9.5	16,000	17,300	10.0	8,700	11,300	8.3	6,900	8,350	9.2
							44,500	48,600	10.0	-	16,200	-	-	11,600	-	6,800	7,800	4.9
Ave.				58,200	62,200	10.5	42,600	47,800	9.7	15,500	16,800	10.0	9,100	11,500	8.2	6,900	8,080	6.8[b]

[a]Not included in average.
[b]Questionable average.

Table B-2

RESULTS OF COMPRESSIVE TESTS OF 14S-T6 CLAD ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time, hr	78°F		200°F		300°F		400°F		500°F		600°F	
	Compressive Yield Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Compressive Yield Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Compressive Yield Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Compressive Yield Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Compressive Yield Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Compressive Yield Strength, psi	Compressive Modulus of Elasticity, 10^6 psi
	69,500	11.0	64,000	10.3	57,400	11.1	47,950	10.5	29,100[a]	9.5	10,450	6.7
0.5	67,000	10.3	59,000	11.4	56,800	10.5	45,200	10.0	22,200	8.5	10,850	7.1
	71,500	10.3	61,400	10.4	55,000	11.0	45,000	11.2	21,600	9.3	-	-
					58,300	8.2[a]						
Ave.			61,450	10.7	56,900	10.9	46,050	10.6	21,900	9.1	10,650	6.9
	69,000	11.0	60,000	10.6	54,000	9.1	40,100	10.0	16,900	9.6	9,600	6.5
2	62,000[a]	10.0	64,000	10.4	55,200	9.2	40,200	11.9[a]	17,600	10.3	11,400	8.4
	68,000	11.0	61,300	10.2	54,500	9.4	43,800	10.0			-	-
Ave.	69,000	10.6	61,750	10.4	54,550	9.2	41,400	10.0	17,250	9.9	10,500	7.4[c]
			64,000	10.2	52,200	9.9	28,700	9.1	12,350	6.8[a]	9,600	6.5
10			63,000	9.5	51,400	10.0	27,500	11.5[a]	11,800	9.9	9,700	6.5
			61,000	11.2	52,300	9.5	33,700[a]	9.6	12,600	9.9	-	-
			63,000	9.1								
Ave.			63,000	10.0[c]	52,000	9.8	28,100	9.4	12,250	9.9	9,650	6.5
			61,500	10.2	50,500	9.8	20,600	7.1[a]	10,750	7.1	b 7,900	6.15
100			61,700	10.9	51,800	10.6[a]	20,200	9.2	10,900	7.1	b 7,650	-
			62,000	9.8	51,800	9.4	20,200	9.8	10,150	11.2[a]	b 7,530	-
			62,900	10.1	53,500	8.1[a]						
					54,750	9.6						
Ave.			62,000	10.2	52,500	9.6	20,300	9.5	10,600	7.1	7,690	-
			63,500	11.0	48,250	9.9	15,200	14.3[a]	9,200	6.0	b 7,010	-
1000			64,200	9.4	47,400	10.4	15,500	9.6	9,500	7.8	b 7,070	-
			58,700	8.5	49,500	10.0	16,800	9.8	9,800	7.2	b 7,000	-
Ave.			62,100	9.6[c]	48,400	10.1	16,100	9.7	9,500	7.0	7,030	-

[a]Not included in average.

[b]Reliable values of modulus of elasticity could not be determined. However, as a result of the rapid yielding of the material, yield strengths could be determined within an accuracy of ± 4%.

[c]Questionable average.

Table B-5

RESULTS OF BEARING TESTS OF 14S-T6 CLAD ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78° F		200°F		300° F		400° F		500° F		600° F	
	Bearing Yield Stress, psi	Ultimate Bearing Stress, psi	Bearing Yield Stress, psi	Ultimate Bearing Stress, psi	Bearing Yield Stress, psi	Ultimate Bearing Stress, psi	Bearing Yield Stress, psi	Ultimate Bearing Stress, psi	Bearing Yield Stress, psi	Ultimate Bearing Stress, psi	Bearing Yield Stress, psi	Ultimate Bearing Stress, psi
	93,000[a]	113,000	87,000	106,000	81,000	95,000	66,500	75,000	31,500	41,200	18,800	22,300
0.5	95,000	115,000	88,500	105,000	82,000	97,500	66,000	79,000	31,000	36,800	19,800	24,500
	91,500	112,000	89,000	106,000	80,000	93,500	64,500	77,500	30,000	35,000	18,000	22,300
Ave.			88,200	105,700	81,000	95,300	65,700	77,200	30,800	37,700	18,900	23,000
	94,000	113,000	88,500	105,000	84,500	98,000	60,000	69,700	22,800	28,600	14,000	18,200
2	94,000	114,000	87,500	107,000	79,500	93,000	58,000	67,600	22,500	27,700	13,200	16,800
	93,500	113,000	90,000	104,000	81,000	95,000	59,000	68,000	22,500	28,000	14,900	18,500
Ave.	93,600	113,000	88,700	105,300	81,700	95,000	59,000	68,400	22,600	28,100	14,000	17,800
			88,000	106,000	80,500	95,500	41,000	48,700	17,500	20,000	12,200	15,400
10			86,000	106,000	80,000	95,500	43,000	51,000	16,500	18,900	12,200	15,700
			89,000	106,000	80,500	95,500	38,000	46,500	17,000	21,400	12,800	15,100
Ave.			87,700	106,000	80,300	95,500	41,000	48,700	17,000	20,100	12,400	15,400
			87,000	104,000	78,500	91,000	33,000	39,300	15,700	18,300	11,600	14,200
100			89,000	107,000	77,000	90,000	31,500	38,300	14,500	18,300	11,600	14,600
			91,000	107,000	-	-	31,000	37,700	14,500	17,600	11,600	14,700
Ave.			89,000	106,000	77,800	90,500	31,800	38,400	14,900	18,100	11,600	14,500
			93,000	106,000	71,000	84,500	25,500	32,800	14,500	18,600	10,400	11,600
1000			89,000	110,000	69,000	83,500	25,500	32,600	14,000	17,900	10,750	12,200
			90,000	106,000			26,000	34,400	13,200	17,900	10,400	12,700
Ave.			91,000	107,300	70,000	84,000	25,700	33,300	13,900	18,100	10,520	12,200

[a]Not included in average.

Table B-4

RESULTS OF TENSILE TESTS OF 3/16-IN. 14S-T6 ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	Ultimate Tensile Stress, psi					
	78°F	200°F	300°F	400°F	500°F	600°F
	68,700	66,000	65,000	62,000	50,200	42,100
0.5	69,300	67,000	64,000	59,000	-	42,800
	67,900	67,000	64,000	61,000	46,400	43,850
Ave.		66,700	64,300	61,000	48,300	42,900
	68,300	67,000	64,000	57,000	28,400	28,500
2	70,200	66,000	64,000	58,000	33,900	29,150
	68,500	67,000	64,000	61,000	32,500	28,250
Ave.	68,800	66,700	64,000	59,000	31,600	28,600
		68,000	64,000	41,000	26,450	23,850
10		66,000	64,000	41,000	23,250	19,350
		67,000	64,000	41,000	25,200	20,500
Ave.		67,000	64,000	41,000	25,000	21,200
		66,000	63,000	33,000	21,700	18,250
100		67,000	63,000	34,000	22,800	15,600
		67,000	63,000	32,000	24,500	21,900
Ave.		66,700	63,000	33,000	23,000	18,600
		68,000	57,000	28,000	27,450 [a]	16,900
1000		68,000	58,000	29,000	26,750 [a]	19,400
		68,000	57,000	28,000	26,150 [a]	16,950
Ave.		68,000	57,300	28,300	26,800[a]	17,750

[a] Questionable values.

Table B-5

RESULTS OF SHEAR TESTS OF 14S-T6 ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time, hr	Ultimate Shear Stress, psi					
	78°F	200°F	300°F	400°F	500°F	600°F
	39,900	41,300	36,300	29,800	16,200	9,000
0.5	42,800	41,200	38,900	30,600	16,100	8,900
	43,100	42,500	37,700	31,000	15,300	9,200
Ave.		41,700	37,600	30,500	15,900	9,000
	43,400	40,000	36,400	27,100	11,100	6,500
2	42,400	40,500	37,300	27,800	11,100	6,500
	42,200	40,200	36,200	27,000	11,300	6,900
Ave.	42,300	40,200	36,600	27,300	11,200	6,600
		42,000	36,300	20,600	8,500	5,800
10		40,900	36,200	19,600	8,700	5,300
		39,900	39,500	21,200	9,300	5,800
Ave.		40,900	37,300	20,500	8,800	5,600
		40,800	34,900	15,300	7,800	5,700
100		40,600	33,500	14,800	8,600	6,500
		40,800	35,100	15,100	7,700	6,800
Ave.		40,700	34,500	15,100	8,000	6,300
		41,200	31,900	12,800	8,700	6,850
1000		40,700	31,900	12,200	8,100	5,800
		40,700	31,600	14,300	7,800	6,000
Ave.		40,900	31,800	13,100	8,200	6,200

Table B-6

RESULTS OF TENSILE TESTS OF CLAD 24S-T81 ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F Yield Tensile Strength, psi	78°F Ultimate Tensile Strength, psi	78°F Tensile Modulus of Elasticity, 10^6 psi	200°F Yield Tensile Strength, psi	200°F Ultimate Tensile Strength, psi	200°F Tensile Modulus of Elasticity, 10^6 psi	300°F Yield Tensile Strength, psi	300°F Ultimate Tensile Strength, psi	300°F Tensile Modulus of Elasticity, 10^6 psi	400°F Yield Tensile Strength, psi	400°F Ultimate Tensile Strength, psi	400°F Tensile Modulus of Elasticity, 10^6 psi
0.5	60,500	66,000	10.5	59,000	61,700	10.95	54,400	56,600	9.0	44,800	48,000	9.3
	64,000	65,500	10.0	58,500	62,300	9.5	54,900	57,600	9.0	46,000	48,000	9.3
	63,000	66,500	9.5		60,600	10.3						
Ave.				58,800	61,500	10.25	54,600	57,100	9.0	45,400	48,000	9.3
2	60,500	64,000	10.0	59,500	63,000	12.0[a]	55,500	59,000	10.5	48,000	48,600	10.0
	62,000	65,500	10.5	57,500	62,300	10.0	56,800	58,800	10.1	46,700	49,000	9.6
	61,500	66,000	11.0		59,100	11.7[a]						
Ave.	61,900	65,600	10.2	58,500	61,500	11.2[a]	56,200	58,900	10.3	47,400	48,800	9.8
10				60,500	64,000	10.1	54,100	57,100	9.5	40,600	43,900	9.7
				60,500	64,000	10.6	54,700	56,700	10.0	39,400	42,700	10.0
					60,200	10.6						
Ave.				60,500	62,700	10.4	54,400	56,900	9.8	40,000	43,300	9.85
100				57,500	65,000	9.7	56,100	56,900	9.5	36,500	39,800	9.0
				60,000	64,500	10.4	55,500	55,900	10.5	36,500	39,300	9.0
					64,400	10.8						
Ave.				58,800	64,600	10.3	55,800	56,400	10.0	36,500	39,600	9.0
1000				60,000	63,000	10.5	55,400	57,600	9.5	26,800	30,300	7.0
				61,000	64,200	11.2	53,400	54,700	10.0	27,500	30,600	8.0
							54,100	55,700	10.6	27,800	31,800	7.4
Ave.				60,500	63,600	10.8	54,300	56,000	10.0	27,400	30,900	7.5

[a]Questionable value.

Table B-7

RESULTS OF COMPRESSIVE TESTS OF 24S-T81 CLAD ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F Yield Compressive Strength, psi	78°F Compressive Modulus of Elasticity, 10^6 psi	200°F Yield Compressive Strength, psi	200°F Compressive Modulus of Elasticity, 10^6 psi	300°F Yield Compressive Strength, psi	300°F Compressive Modulus of Elasticity, 10^6 psi	400°F Yield Compressive Strength, psi	400°F Compressive Modulus of Elasticity, 10^6 psi
	-	10.9	60,800	10.0	57,700	12.9[a]	53,000	10.2
0.5	71,000	10.5	62,000	10.1	59,900	10.1	43,600[a]	7.1[a]
	-	10.0	62,300	10.4	61,300	10.1	50,300	10.7
	67,800	11.2						
	69,000	10.6						
	69,400	10.1						
Ave.	69,300	10.6	61,700	10.2	59,600	10.1	51,700	10.4
			63,500	14.0[a]	60,350	9.5	49,800	10.4
2			63,200	11.0	61,000	9.5	48,800	10.1
			63,400	10.5	60,150	9.4	48,800	11.7[a]
Ave.			63,400	10.8	60,500	9.5	49,100	10.2
			64,000	8.9[a]	58,800	9.8	45,200	11.0
10			63,000	10.8	55,200	10.9	43,800	10.8
			63,000	10.1	58,300	10.1	46,000	11.0
							48,000	8.4[a]
							47,600	9.7
Ave.			63,300	10.4	57,400	10.3	47,650	10.7
			63,100	10.4	59,000	10.6	38,600	10.2
100			63,500	11.1	59,350	10.1	40,300	12.6[a]
			60,000	10.4	60,600	9.7	42,300	8.9
							42,900	8.3
Ave.			62,300	10.6	59,700	10.1	40,050	9.1
			63,500	10.9	56,200	9.4	28,100	11.0
1000			67,500[a]	11.1	52,900	9.3	28,900	10.8
			61,100	10.3	56,500	9.7	27,900	9.9
Ave.			62,300	10.8	55,200	9.5	28,300	10.6

[a]Not included in average.

Table B-8

RESULTS OF BEARING TESTS OF 24S-T81 CLAD ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F Yield Bearing Strength, psi	78°F Ultimate Bearing Strength, psi	200°F Yield Bearing Strength, psi	200°F Ultimate Bearing Strength, psi	300°F Yield Bearing Strength, psi	300°F Ultimate Bearing Strength, psi	400°F Yield Bearing Strength, psi	400°F Ultimate Bearing Strength, psi
	90,000	101,000	87,000	101,500	84,500	95,000	73,000	81,200
0.5	93,000	102,000	88,500	101,600	85,000	94,400	75,500	83,100
			88,000	101,300	85,200	92,700	74,500	82,200
Ave.			87,800	101,500	84,900	94,000	74,400	82,200
	91,000	103,000	90,000	101,100	82,500	93,800	71,500	78,800
2	91,500	104,000	90,000	100,200	82,800	92,800	70,500	77,500
	90,500	105,000	89,000	100,800	83,500	94,100	75,000	83,000
Ave.	91,200	103,000	89,700	100,700	82,900	93,600	72,300	79,800
			90,000	100,800	84,200	93,600	64,800	73,100
10			88,000	100,500	81,500	93,100	65,800	73,100
			87,000	104,900	82,200	94,700	62,500	69,700
Ave.			88,400	102,100	82,600	93,800	64,400	72,000
			87,000	100,500	85,000	95,900	58,500	65,600
100			86,500	99,800	85,500	94,700	54,800	64,100
			88,000	100,200	81,500	90,500	56,000	62,800
Ave.			87,200	100,200	84,000	93,700	56,400	64,200
			89,200	101,100	82,400	93,100	48,000	57,800
1000			89,800	100,800	82,000	93,800	44,000	59,100
			89,000	102,000	86,000	94,500		
Ave.			89,300	101,300	83,500	93,800	46,000	58,400

Table B-9

RESULTS OF SHEAR TESTS AND TENSILE TESTS OF 3/16-INCH 24S-T81 ALUMINUM ALLOY SHEET AT ELEVATED TEMPERATURES

Time hr	SHEAR 78°F Ultimate Shear Strength, psi	SHEAR 200°F Ultimate Shear Strength, psi	SHEAR 300°F Ultimate Shear Strength, psi	SHEAR 400°F Ultimate Shear Strength, psi	TENSION (3/16-IN. SHEET) 78° Ultimate Tensile Strength, psi	TENSION (3/16-IN. SHEET) 200°F Ultimate Tensile Strength, psi	TENSION (3/16-IN. SHEET) 300°F Ultimate Tensile Strength, psi	TENSION (3/16-IN. SHEET) 400°F Ultimate Tensile Strength, psi
	40,900	39,700	35,500	33,300	67,600	67,000	65,600	62,600
0.5	40,900	39,200	36,100	32,000	68,700	67,500	64,400	64,200
	40,900	39,000	35,500	32,300	68,400	65,800	66,000	63,700
Ave.		39,300	35,700	32,500		66,800	65,300	63,500
	40,500	39,500	35,500	32,500	68,900	66,700	65,600	62,400
2	40,600	37,900	35,300	32,000	69,000	66,800	63,900	63,600
	41,100	39,000	35,200	32,000	67,500	65,800	63,900	62,600
Ave.	40,800	38,800	35,300	32,200	68,400	66,400	64,500	62,900
		38,700	34,900	29,100		66,900	63,800	58,800
10		37,900	35,300	30,400		65,500	65,000	57,900
		39,800	37,000	28,200		66,300	64,300	59,200
Ave.		38,800	35,700	29,200		66,200	64,400	58,600
		37,800	36,600	26,600		66,400	65,200	51,600
100		39,000	38,900	27,300		66,500	64,500	51,000
		38,800	37,700	25,900		65,800	65,500	50,700
Ave.		38,500	37,700	26,600		66,200	65,100	51,100
		38,900	34,300	20,770		68,400	64,200	41,800
1000		38,000	34,600	22,510		68,000	63,400	39,100
		37,800	34,550	21,660		66,700	63,400	38,300
Ave.		38,200	34,500	21,600		67,700	63,700	39,700

Table B-10

RESULTS OF TENSILE TESTS OF 24S-T86 CLAD ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F			200°F			300°F			400°F		
	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi
	68,000	73,000	15.0[a]	64,000	68,000	10.4	62,000	64,700	10.7	53,000	54,200	9.3
0.5	69,300	73,000	11.0[b]	63,000	68,000	9.4	62,000	65,300	9.8	53,000	54,600	9.7
	71,000	73,000	11.7[b]									
Ave.				63,500	68,000	9.9	62,000	65,000	10.3	53,000	54,400	9.6
	68,500	72,200	11.0[b]	62,300	67,400	10.4	62,000	64,300	10.9	52,000	52,300	10.3
2	63,800	72,500	11.0[b]	64,500	68,700	10.1	62,200	63,300	11.5[a]	51,300	51,300	9.0
							61,800	64,100	10.6	34,600[a]	38,300[a]	9.4
							-	63,800	7.3[a]			
							-	62,500	9.7			
Ave.	69,100	72,700	11.2[a]	63,600	68,000	10.2	62,000	63,600	10.4	51,600	51,800	9.6
				65,000	67,700	10.7	62,300	64,000	9.4	41,700	45,200	10.8
				63,500	68,200	11.9[a]	61,800	64,500	10.7	41,800	45,000	9.2
10				-	68,500	10.3	-	61,600	7.6[a]	-	42,200	9.75
				-	66,500	10.7	-	60,200	9.95			
					67,400	10.1	61,500	62,900	10.2			
Ave.				64,200	68,500	10.4	61,900	62,600	10.1	41,750	44,100	9.9
				65,000	69,500	12.3[a]	61,800	62,700	10.4	37,000	41,000	10.0
100				63,000	68,500	10.0	63,000	63,500	10.6	38,000	41,200	10.0
				-	67,500	10.1	-	65,500	10.2			
Ave.				64,000	68,500	10.1	62,400	63,900	10.4	37,500	41,100	10.0
				66,000	70,500	10.6	54,000	56,500	11.1	27,800	29,800	8.7
1000				65,500	70,000	10.3	57,000	57,500	9.7	28,400	30,400	8.0
				63,000	68,000	11.2	58,400	58,500	11.1	27,200	30,100	8.4
Ave.				64,800	69,500	10.7	56,500	57,500	10.6	27,800	30,100	8.4

[a]Not included in average.

[b]Room temperature modulus values are higher than normal for this material.

Table B-11

RESULTS OF COMPRESSIVE TESTS OF 24S-T86 CLAD ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F Yield Compressive Strength, psi	78°F Compressive Modulus of Elasticity, 10^6 psi	200°F Yield Compressive Strength, psi	200°F Compressive Modulus of Elasticity, 10^6 psi	300°F Yield Compressive Strength, psi	300°F Compressive Modulus of Elasticity, 10^6 psi	400°F Yield Compressive Strength, psi	400°F Compressive Modulus of Elasticity, 10^6 psi
	74,900	10.5	70,000	9.2[a]	68,300	9.85	42,600[a]	11.5[a]
0.5	72,800	10.7	69,500	10.2	68,800	9.2[a]	61,000	10.6
	74,500	10.5	71,600	10.6	70,500	9.85	60,200	10.4
Ave.			70,400	10.4	69,200	9.85	60,600	10.5
	72,700	10.2	73,800	10.8	68,700	10.4	56,000	10.8
2	74,100	10.3	70,800	10.9	66,800	10.6	53,500	10.2
	78,300	10.8	69,000	10.9	68,100	10.6	55,300	10.5
							54,000	9.25[a]
							51,700	8.5[a]
Ave.	74,500	10.5	71,200	10.9	67,900	10.5	54,100	10.5
			69,200	10.7	70,000	10.2	48,000	10.3
10			67,600	10.4	64,000	11.5[a]	50,000	10.0
			72,300	9.7	67,400	10.0	44,900	10.5
Ave.			69,700	10.3	67,100	10.1	47,600	10.3
			70,500	10.4	68,800	10.4	43,200	10.0
100			70,200	10.1	66,700	9.8	40,600	10.4
			70,500	9.2[a]	66,400	10.2	40,100	10.3
Ave.			70,400	10.2	67,300	10.1	41,300	10.2
			67,600	9.7	65,200	10.2	28,000	11.8[b]
1000			71,900	10.5	61,500	10.2	36,000[a]	13.7[ab]
			71,550	10.0	57,500	10.8	25,800	11.8[b]
Ave.			70,350	10.1	61,400	10.4	26,900	11.8[b]

[a]Not included in average.

[b]Questionable value.

Table B-12

RESULTS OF BEARING TESTS OF 24S-T86 CLAD ALUMINUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F Yield Bearing Strength, psi	78°F Ultimate Bearing Strength, psi	200°F Yield Bearing Strength, psi	200°F Ultimate Bearing Strength, psi	300°F Yield Bearing Strength, psi	300°F Ultimate Bearing Strength, psi	400°F Yield Bearing Strength, psi	400°F Ultimate Bearing Strength, psi
	96,000	109,000	96,500	110,000	94,000	106,200	83,500	91,000
0.5	104,000	117,000	97,500	111,000	94,500	103,200	80,000	86,500
	101,000	113,000	98,000	110,500	94,000	106,000	81,000	88,300
Ave.			97,300	110,500	94,150	105,100	81,500	89,600
	95,500	113,000	95,000	108,800	91,000	103,000	76,500	84,000
2	101,000	113,000	99,500	112,000	91,000	102,500	71,500	80,300
	99,000	113,000	90,500	103,700	91,500	101,000	72,000	80,000
Ave.	100,200	113,000	95,000	108,150	91,150	102,150	73,300	81,400
			96,000	112,000	91,000	102,000	66,500	74,000
10			97,000	112,500	92,000	103,000	63,500	73,200
			98,500	110,500	94,000	106,000	65,000	71,500
Ave.			97,200	111,650	92,300	103,650	65,000	72,900
			94,000	108,500	92,500	103,500	61,000	70,700
100			94,500	107,500	91,000	101,000	59,000	67,000
			98,000	108,000	94,000	105,500	61,000	69,500
Ave.			95,500	108,000	92,500	103,300	60,300	69,050
			93,000	105,000	84,000	94,500	50,000	57,300
1000			98,000	113,000	83,500	95,100	45,000	53,300
			100,000	111,500	82,000	92,800	44,500	53,900
Ave.			97,000	109,800	83,150	94,100	46,500	54,800

Table B-13

RESULTS OF SHEAR TESTS AND TENSILE TESTS OF 3/16-INCH 24S-T86 ALUMINUM ALLOY SHEET AT ELEVATED TEMPERATURES

Time hr	Shear Test: Ultimate Shear Strength, psi				Tensile Test (3/16-in. Sheet): Ultimate Tensile Strength, psi			
	78°F	200°F	300°F	400°F	78°F	200°F	300°F	400°F
	45,400	43,800	41,000	37,600	74,200	72,600	71,100	67,800
0.5	45,500	42,900	41,900	35,500	73,600	75,400	71,450	69,650
	44,500	45,500	40,450	37,800	75,800	73,650	71,200	70,950
Ave.		43,100	41,100	37,000		73,900	71,250	69,450
	45,600	43,700	39,700	32,300	74,200	74,100	71,150	68,750
2	44,800	43,350	40,050	32,000	75,600	72,400	71,600	69,350
	45,700	43,650	40,300	32,800	75,700	72,650	72,150	67,750
Ave.	45,300	43,200	40,000	32,400	74,850	73,050	71,600	68,600
		43,630	43,500	27,400		73,700	71,750	60,050
10		42,240	43,450	27,250		72,550	71,750	59,200
		43,680	41,600	27,650		74,000	69,350	57,900
Ave.		43,200	42,800	27,400		73,400	71,000	59,050
		43,200	41,200	26,500		74,600	70,200	54,950
100		41,750	42,100	26,000		74,900	71,250	53,850
		44,360	41,800	25,850		74,100	69,550	51,950
Ave.		43,100	41,700	26,100		74,500	70,300	53,600
		42,400	35,270	19,100		75,300	66,000	39,250
1000		44,400	34,610	19,000		76,050	67,300	37,650
		44,000	35,270	18,600		75,250	66,900	40,750
Ave.		43,600	35,000	18,900		75,500	66,700	39,200

Table B-14

RESULTS OF TESTS OF FS1-H24 MAGNESIUM ALLOY SHEET MATERIAL AT 200°F

	Tension (.064 in. Sheet)			Compression		Bearing		Shear		Tension (1/4-in. Sheet)
								Ultimate Shear Strength, psi		
Time hr	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Yield Compressive Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Yield Bearing Strength, psi	Ultimate Bearing Strength, psi	Room Temperature	200°F	Ultimate Tensile Strength, psi
	25,500	34,800	6.5	27,500[a]	6.25[a]	41,000	55,800	23,400	23,000	39,000
0.5	24,000	35,400	7.5	22,400	5.7	40,500	54,500	24,200	19,000[a]	40,100
				22,700	5.5	39,000	55,000	23,400	15,100[a]	39,200
								22,100	23,460	
									22,130	
Ave.	24,800	35,100	7.0	22,550	5.6	40,200	55,100	23,300	22,900	39,400
	26,700	33,700	6.3	23,550	4.7	39,000	53,400		24,400	38,300
1000	25,500	33,600	10.0[a]	23,000	5.7	39,000	49,700		20,000	39,100
	26,000	33,000	6.3			40,500	53,400		21,800	39,000
Ave.	26,100	33,400	6.3	23,300	5.2	39,500	52,200		22,100	38,800

[a]Not included in average.

Table B-15

RESULTS OF TESTS OF 75S-T6 CLAD ALUMINUM ALLOY SHEET MATERIAL AT 200°F

Time hr	Tensile (.064 in. Sheet) Yield Tensile Strength, psi	Tensile (.064 in. Sheet) Ultimate Tensile Strength, psi	Tensile (.064 in. Sheet) Tensile Modulus of Elasticity, 10^6 psi	Compression Yield Compressive Strength, psi	Compression Compressive Modulus of Elasticity, 10^6 psi	Bearing Yield Bearing Strength, psi	Bearing Ultimate Bearing Strength, psi	Shear Ultimate Shear Strength, psi	Tensile (3/16 in. Sheet) Ultimate Tensile Strength, psi
	63,000	65,200	10.7	64,500	9.6	91,000	110,000	44,800	74,800
0.5	62,000	67,500	9.5	68,750	9.6	92,000	110,000	44,800	75,400
	60,800	66,000	10.2	64,700	9.9	94,000	111,000	47,300	75,400
Ave.	61,900	66,200	10.1	66,000	9.7	92,300	110,300	45,600	75,200
	63,000	66,500	9.9	60,600	10.0	91,000	111,000	45,400	73,700
2	59,300	66,500	10.0	65,000	11.7[a]	91,000	112,000	44,700	75,000
		66,500	10.1	60,400	10.3	92,000	109,000	45,800	
Ave.	61,200	66,500	10.0	62,000	10.15	91,300	111,000	45,300	74,400
	60,000	66,500	9.5	66,700	10.1	87,500	104,000	47,300	74,300
10	60,900	67,500	10.5	64,500	9.2	92,000	109,000	45,000	75,500
		68,000	9.3			91,000	111,000	45,000	75,200
Ave.	60,450	67,300	9.8	65,600	9.7	90,200	108,000	45,800	75,000
	60,500	67,000	9.65	66,700	10.4	91,000	109,000	48,100	73,000
100	60,000	66,200	9.0	66,700	10.2	88,500	111,000	46,600	74,000
		67,800	10.3	68,000	9.4	92,000	112,000	46,700	74,400
Ave.	60,200	67,000	9.65	67,100	9.9	90,500	110,700	47,100	73,800
	57,500	65,000	9.2	64,200	9.9	95,000	112,000	46,100	76,000
1000	53,500	65,500	9.2	61,800	10.2	95,500	115,000	46,700	75,700
		65,800	11.6[a]	66,050	10.0	95,000	112,500	47,600	75,600
Ave.	55,500	65,400	9.2	64,000	10.0	95,200	113,200	46,800	75,800

[a]Not included in average.

Table B-16

RESULTS OF TESTS OF COLD ROLLED TITANIUM SHEET MATERIAL AT 200°F

	Tensile (.064 in. Sheet)			Compression		Bearing		Shear	Tensile (3/16 in. Sheet)
Time hr	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Compressive Yield Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Yield Bearing Strength, psi	Ultimate Bearing Strength, psi	Ultimate Shear Strength, psi	Ultimate Tensile Strength, psi
	75,000	75,900	14.0	78,600	13.3	116,000	128,000	52,300	94,600
0.5	71,000	78,000	19.0	74,500	12.8	113,000	127,000	56,000	94,100
	68,000	76,500	19.0	84,900[a]	14.3	106,000	121,000	56,200	95,000
				69,750[a]	14.9				
				74,800	16.2[a]				
Ave.	71,300	76,800	17.3	75,970	13.8	112,000	125,000	54,800	94,600
	83,000	87,000	15.5	82,000	13.7	110,000	124,500	66,200	98,400
	79,000	87,000	15.5	79,200	18.0[a]	116,000	126,000	62,400	92,200
100	74,000	85,000	14.0	77,200	16.8	110,000	126,000	58,300[a]	95,400
				75,600	11.4[a]			64,500	
				73,400	14.1			63,000	
Ave.	78,700	86,300	15.0	77,500	14.9	112,000	125,500	64,000	95,300

[a] Not included in average.

Table B-17

RESULTS OF TESTS OF ANNEALED TITANIUM SHEET MATERIAL AT 200°F

Time hr	Tensile (.064 in. Sheet) Yield Tensile Strength, psi	Tensile (.064 in. Sheet) Ultimate Tensile Strength, psi	Tensile (.064 in. Sheet) Tensile Modulus of Elasticity, 10^6 psi	Compression Compressive Yield Strength, psi	Compression Compressive Modulus of Elasticity, 10^6 psi	Bearing Yield Bearing Strength, psi	Bearing Ultimate Bearing Strength, psi	Shear Ultimate Shear Strength, psi	Tensile (3/16 in. Sheet) Ultimate Tensile Strength, psi
	43,000	71,000	18.0	61,600[a]	19.7[a]	63,500	91,000	58,900	65,800
0.5	50,200	64,500	16.7	55,500	14.0	70,500	97,500	54,400	64,200
	51,500	66,000	14.7	52,600	13.5	61,000	88,000	57,300	61,800
				55,100	14.3				
				47,700[a]	13.5				
Ave.	48,200	67,200	16.5	54,400	13.8	65,000	92,200	56,900	63,900
	53,600	66,500	16.8	48,900	13.8	67,500	96,500	49,700	63,500
	50,200	65,900	14.7	55,250	16.1	69,500	99,000	56,000	62,700
100	45,100	61,500	15.9	53,500	13.7	68,000	97,000	49,900	64,300
				41,750[a]	9.3[a]			47,900	
				45,200	11.3[a]			57,500	
								68,500[a]	
Ave.	49,600	64,600	15.8	50,700	14.3	68,300	97,500	52,200	64,100

[a]Not included in average.

Table B-18

RESULTS OF TENSILE TESTS OF RC-130-A TITANIUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F			300°F			500°F			600°F			800°F		
	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi	Yield Tensile Strength, psi	Ultimate Tensile Strength, psi	Tensile Modulus of Elasticity, 10^6 psi
	126,000	134,000	17.0	96,600	118,000	16.5	79,200	105,800	11.3	87,000	106,300	13.0	68,700	93,200	12.2
0.5	131,500	133,000	18.0	102,000	119,000	18.3	72,100	105,100	19.5[a]	-	106,800	13.9	69,300	95,550	13.3
	129,000	133,000	19.0				74,000	99,000	12.9	58,000[a]	97,700[a]	11.2[a]	73,000	96,350	9.7
							74,300	106,700	10.7	77,500	102,500	12.8			
										80,600	99,000	14.2			
										94,600[a]	119,000[a]	14.0			
Ave.	128,800	133,300	18.0	99,300	118,500	17.4	74,900	104,100	11.6	81,500	103,600	13.6	70,300	95,000	11.7
				96,000	116,000	20.4	93,000	113,300	15.9	90,200	108,000	17.6	71,500	94,000	13.9
100				94,000	116,800	16.7	91,300	112,600	18.1	86,500	105,400	16.0	70,500	91,450	9.5
										87,500	108,400	13.3	-	93,650	-
Ave.				95,000	116,400	16.6	92,100	113,200	17.0	88,100	107,300	15.6	71,000	93,000	11.7
				103,750	123,500	16.95	77,300	106,400	14.5	77,000	103,500	14.6	Data for this condition were not available in time for publication in the report. They will be presented in the reports for the next supplement of the program.		
1000				104,200	123,500	17.95	79,000	108,200	14.4	85,300	105,000	19.6			
				91,100	108,400	16.75	74,300	108,800	16.4	68,900	99,300	13.4			
Ave.				99,700	118,450	17.2	77,000	107,800	15.1	77,100	102,600	15.9			

[a]Not included in average.

Note: Tests were performed at 1000°F for all exposure periods appearing in this table. The results of these tests will be presented in future reports.

Table B-19

RESULTS OF COMPRESSIVE TESTS OF RC-130-A TITANIUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F		300°F		500°F		600°F		800°F	
	Yield Compressive Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Yield Compressive Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Yield Compressive Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Yield Compressive Strength, psi	Compressive Modulus of Elasticity, 10^6 psi	Yield Compressive Strength, psi	Compressive Modulus of Elasticity, 10^6 psi
	126,700[a]	17.4	110,100	16.8	85,200	18.9[a]	109,600[a]	14.1	87,300	9.9
0.5	138,300	17.1	88,500[a]	15.4	79,200[a]	11.9[a]	73,850[a]	14.1	84,400	12.1
	127,000[a]	16.9	85,700[a]	14.3	76,700[a]	13.6	103,000	16.4[a]	60,000[a]	10.1
			103,600	15.8	86,400	15.0	81,200	12.6		
			109,300	15.3	83,900	14.0	96,500	13.8		
Ave.			107,700	15.6	85,200	14.1	93,600	13.7	85,850	10.4
	137,000	17.4	105,200[a]	18.1[a]	96,800	16.9[a]	95,900	11.2	67,100	10.9
100	107,500[a]	14.9[a]	93,000	16.8	85,700	17.3[a]	88,000	13.7	63,200	15.6
	144,000	14.0[a]	91,400	14.5	73,100[a]	15.0	83,450	13.5		
	140,000	16.4	113,500[a]	16.2	83,800	13.6				
			87,500	14.1	97,100	15.5				
Ave.	139,800	17.0	90,600	15.4	90,850	14.7	89,100	12.8	65,150	13.2
			114,700	16.5	81,100	11.5	77,800	11.7	Data for this condition were not available in time for publication in the report. They will be presented in the reports for the next supplement of the program.	
1000			110,000	16.1	81,600	14.0	96,000	12.0		
			97,000	20.4[a]	91,800	15.4	95,000	13.7		
Ave.			107,200	16.2	84,800	13.6	89,600	12.5		

[a]Not included in average.

Note: Tests were performed at 1000°F for all exposure periods appearing in this table. The results of these tests will be presented in future reports.

Table B-20

RESULTS OF BEARING TESTS OF RC-130-A TITANIUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	78°F Yield Bearing Strength, psi	78°F Ultimate Bearing Strength, psi	300°F Yield Bearing Strength, psi	300°F Ultimate Bearing Strength, psi	500°F Yield Bearing Strength, psi	500°F Ultimate Bearing Strength, psi	600°F Yield Bearing Strength, psi	600°F Ultimate Bearing Strength, psi	800°F Yield Bearing Strength, psi	800°F Ultimate Bearing Strength, psi
	155,100	207,000	100,200[a]	161,000[a]	127,000	162,000	108,600	141,300	122,000	148,000
0.5	143,400[a]	177,500[a]	112,000[a]	147,000[a]	123,000	161,000	114,500	148,000	117,500	146,000
	152,200	198,000	151,000	187,000	131,200	166,000	128,400	164,500	110,000	142,000
	138,600[a]	173,000[a]	146,500	183,000	134,000	168,200	119,000	157,500		
			131,000[a]	167,000[a]	123,300	162,500	118,100	146,800		
			148,700	188,400						
Ave.	153,700	202,500	148,700	186,100	127,700	163,900	117,700	151,600	116,500	145,300
			129,000	168,000	103,800[a]	132,200[a]	102,700	129,600	118,000	145,000
100			132,500	167,000	139,000	169,000	104,000	131,200	119,800	146,600
			144,000	184,000	137,800	168,000			111,000	141,000
Ave.			135,200	173,000	138,400	168,500	103,300	130,400	116,250	144,200
			143,300	179,250	137,200	167,100	129,000	158,500	Data for this condition were not available in time for publication in this report. They will be presented in the reports for the next supplement of the program.	
1000			134,750	175,500	132,500	170,500	128,000	162,000		
			139,400	173,600	136,100	168,500	129,000	162,000		
Ave.			139,150	176,100	135,300	168,500	128,650	160,800		

[a]Not included in average.

Note: Tests were performed at 1000°F for all exposure periods appearing in the table. The results of these tests will be presented in future reports.

Table B-21

RESULTS OF SHEAR TESTS OF RC-130-A TITANIUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	Ultimate Shear Strength, psi				
	78°F	300°F	500°F	600°F	800°F
	92,000	89,500	85,900	81,200	67,650
0.5	97,300	87,000	75,300	79,500	75,100
	108,400	91,700	81,200	73,200	68,450
	104,300		72,700	76,500	
	102,800		95,100	77,300	
Ave.	101,400	89,400	82,000	77,500	70,400
		85,800	79,500	74,200	70,600
100		85,600	83,000	78,300	69,500
		92,100	79,900	74,600	74,300
		79,500[a]			
		91,300			
		96,000[a]			
Ave.		88,700	80,800	75,700	71,450
		92,750	88,000	90,750[a]	Data for this condition were not available in time for publication in the report. They will be presented in the reports for the next supplement of the program.
1000		86,650	81,500	79,700	
		90,600	71,400	76,350	
Ave.		90,000	80,300	78,000	

[a]Not included in average.

Note: Tests were performed at 1000°F for all exposure periods appearing in this table. The results of these tests will be presented in future reports.

Table B-22

RESULTS OF TENSILE TESTS OF 3/16-INCH RC-130-A TITANIUM ALLOY SHEET MATERIAL AT ELEVATED TEMPERATURES

Time hr	Ultimate Tensile Strength, psi				
	78°F	300°F	500°F	600°F	800°F
0.5	139,600	116,900	106,850	103,300	91,200
	137,700	113,400	106,700	99,000	91,800
	141,400				
	142,400				
Ave.	140,300	115,150	106,800	101,150	91,500
100		118,400	114,900	112,450	104,150
		114,000	112,750	111,480	105,400
Ave.		116,200	113,800	111,950	104,750
1000		118,800	115,600	145,480	Data for this condition were not available in time for publication in the report. They will be presented in the reports for the next supplement of the program.
		115,100	106,450	130,100	
Ave.		116,950	111,000	137,800	

APPENDIX C

STRESS-STRAIN AND STRESS-DEFORMATION CURVES

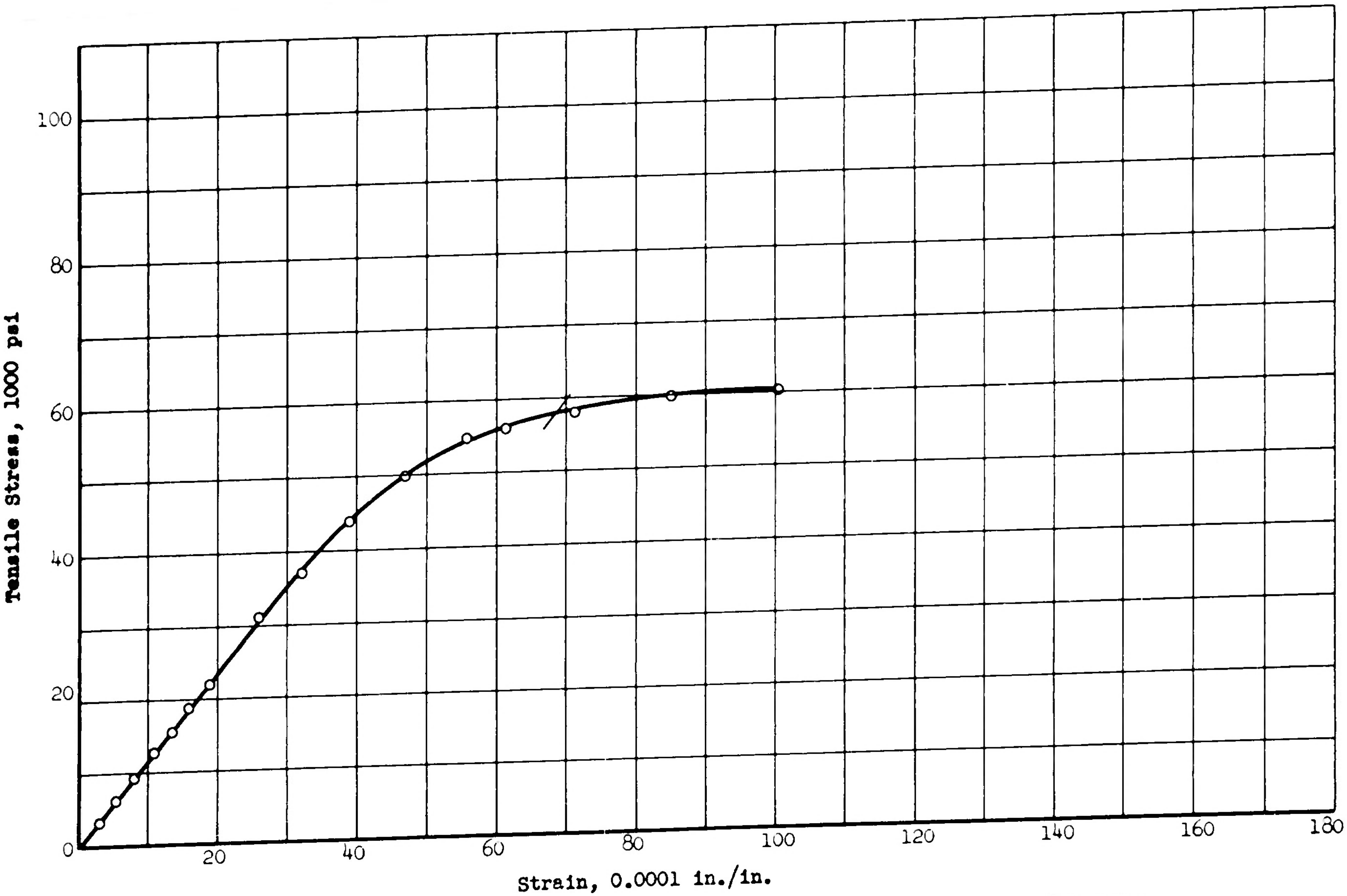

Fig. C-1 TENSILE STRESS-STRAIN CURVE FOR 14S-T6 ALUMINUM ALLOY AT ROOM TEMPERATURE

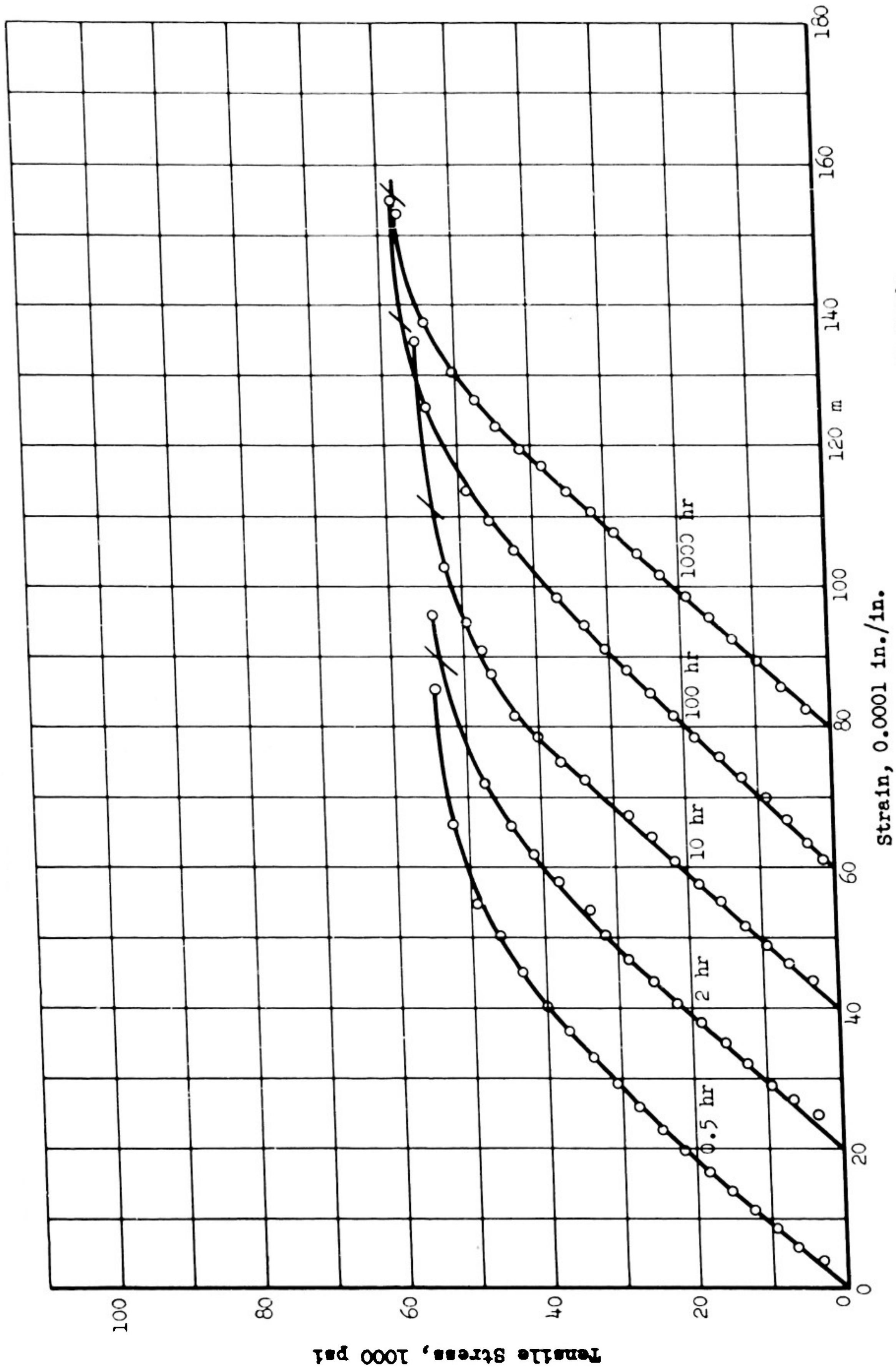

Fig. C-2 TENSILE STRESS-STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 200°F

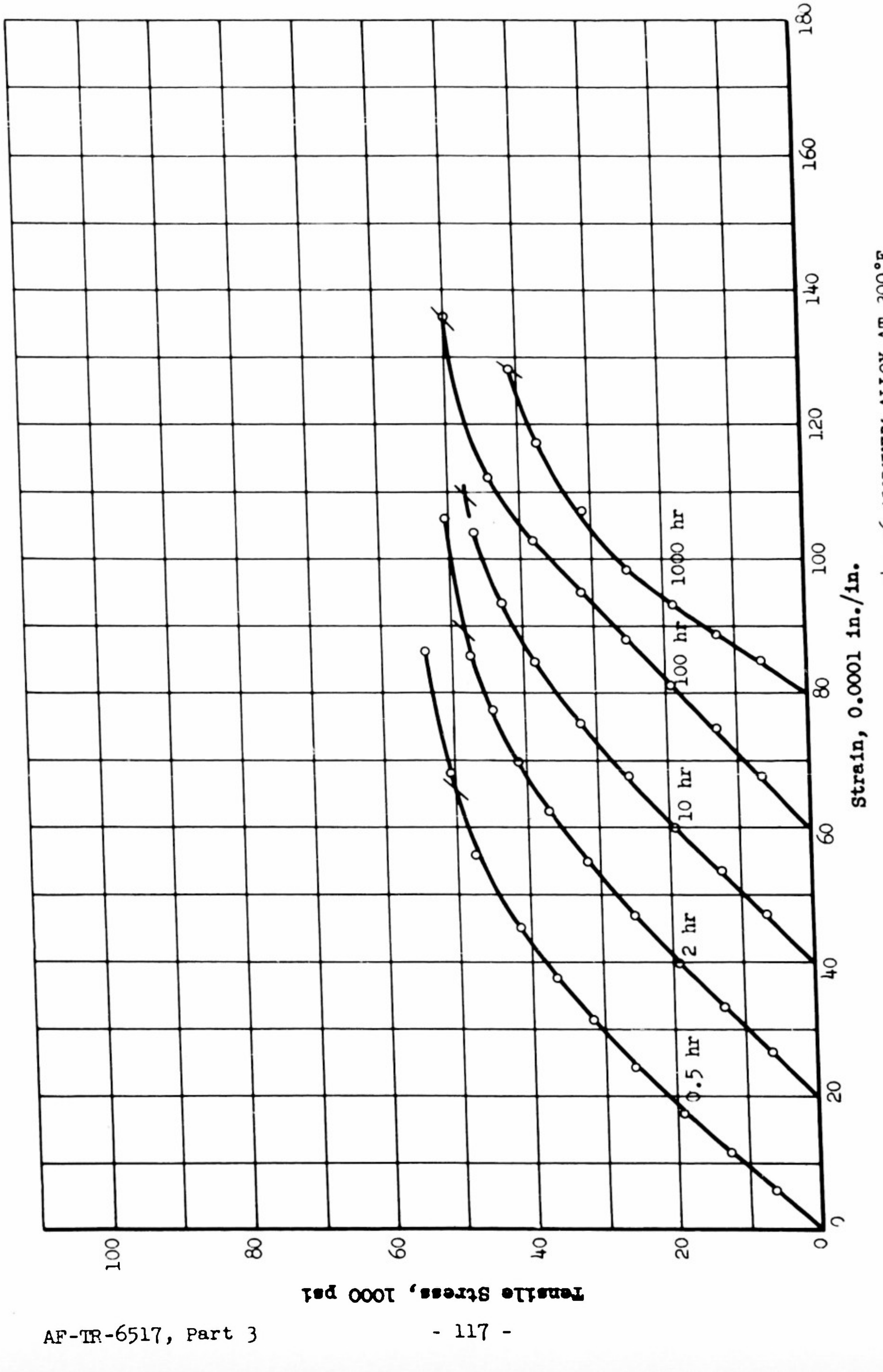

Fig. C-3 TENSILE STRESS-STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 300°F

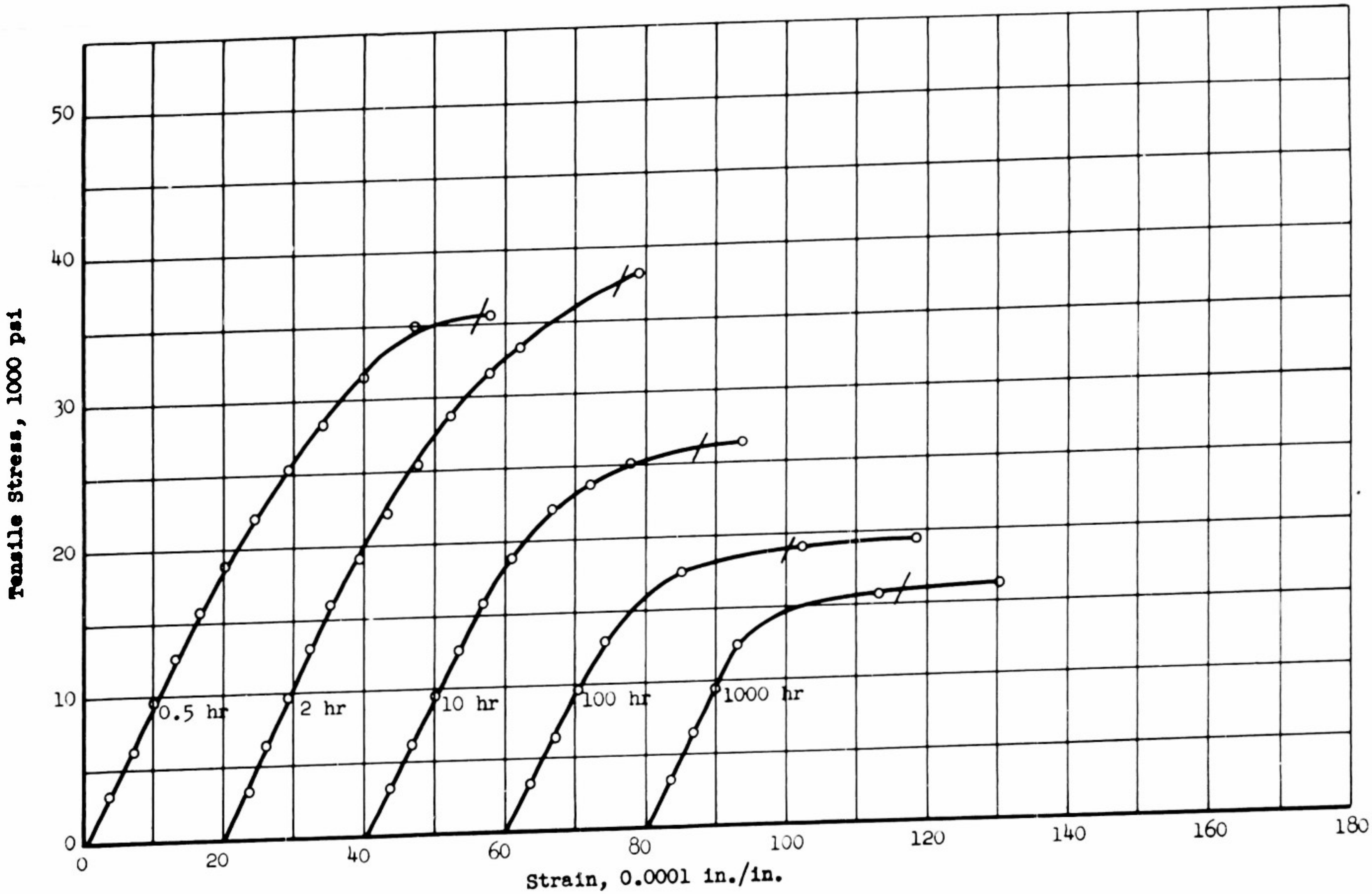

Fig. C-4 TENSILE STRESS-STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 400°F

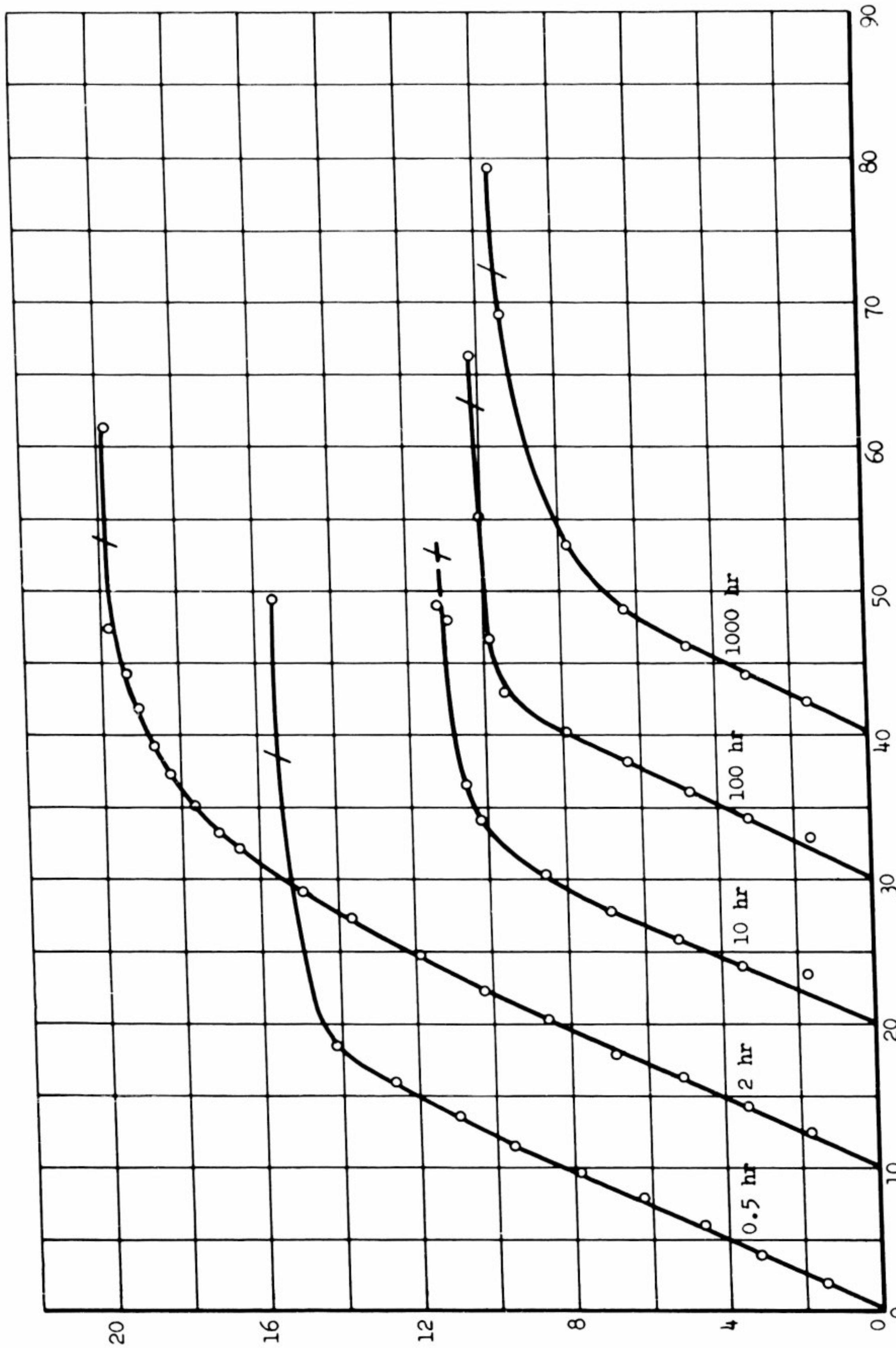

Fig. C-5 TENSILE STRESS-STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 500°F

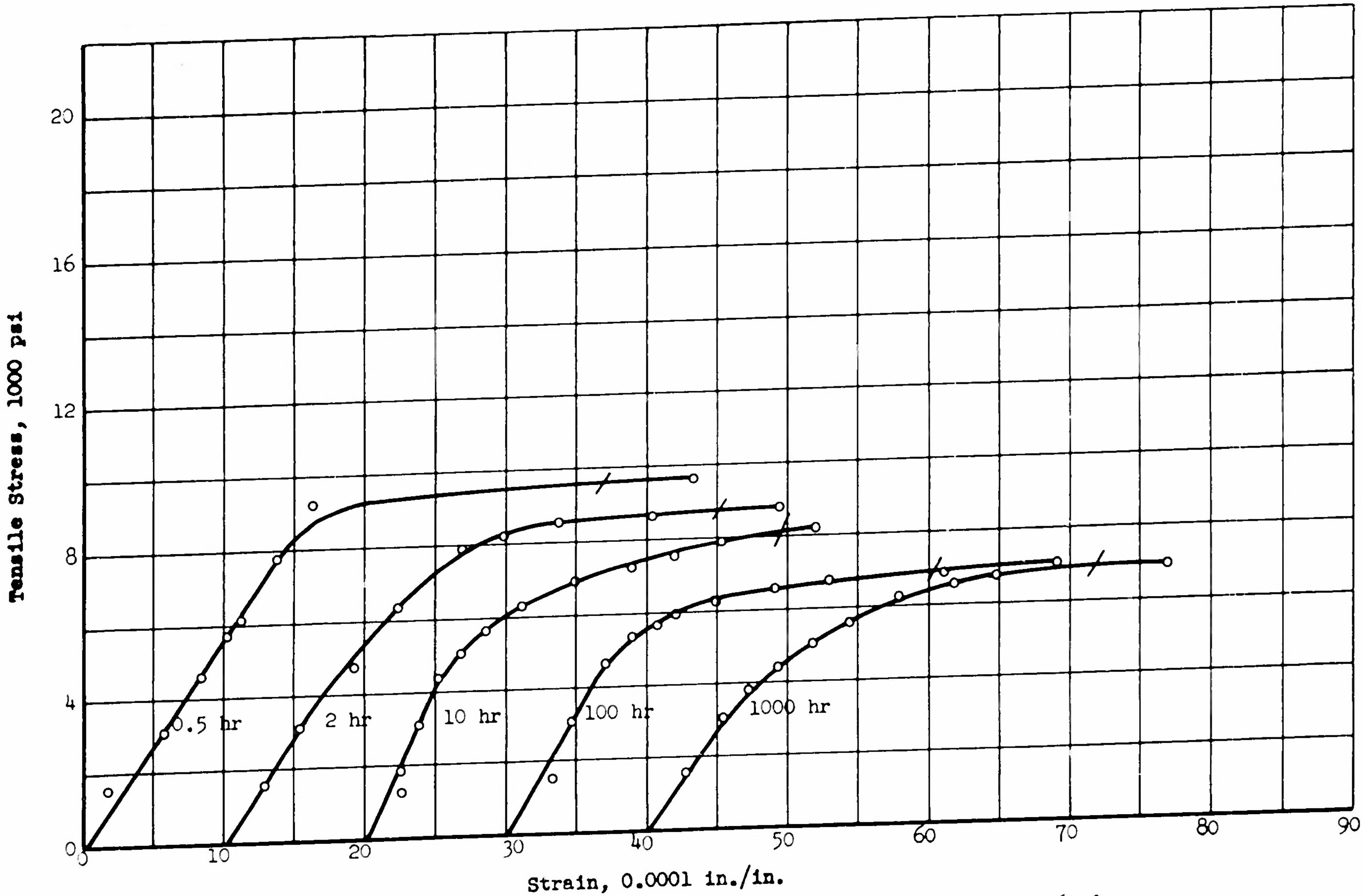

Fig. C-6 TENSILE STRESS-STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 600°F

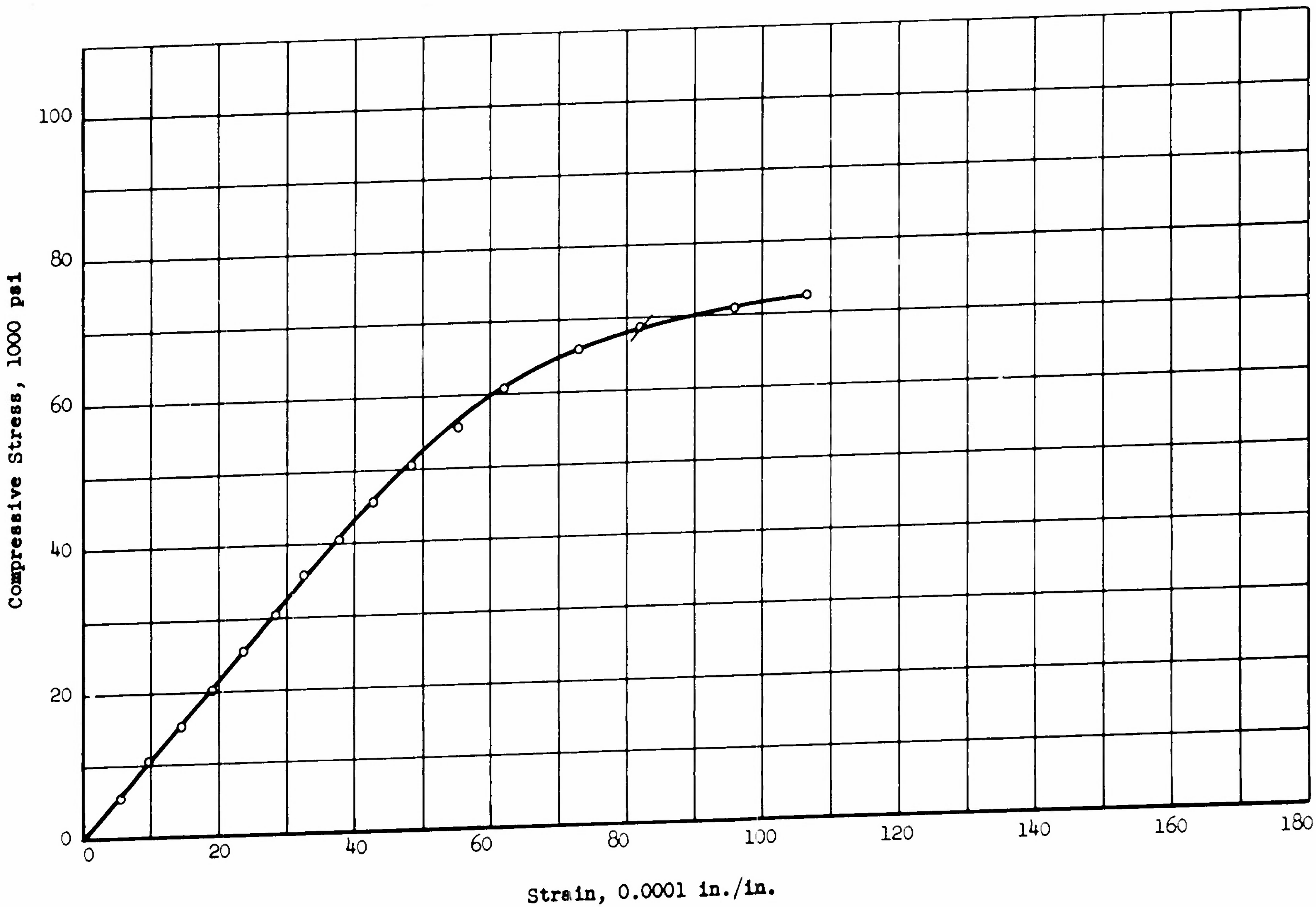

Fig. C-7 COMPRESSIVE STRESS-STRAIN CURVE FOR 14S-T6 ALUMINUM ALLOY AT ROOM TEMPERATURE

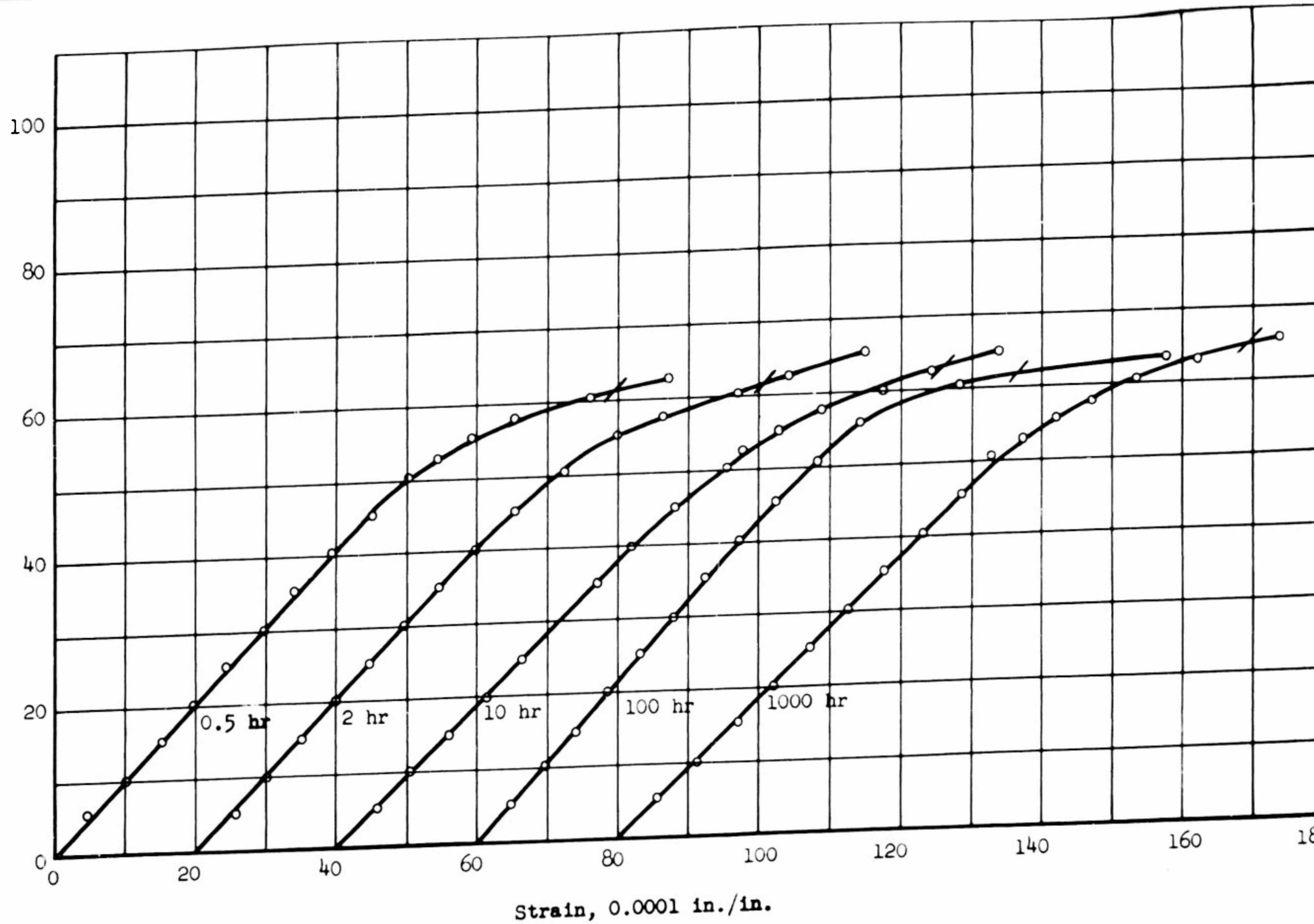

Fig. C-8 COMPRESSIVE STRESS-STRAIN CURVE FOR 14S-T6 ALUMINUM ALLOY AT 200°F

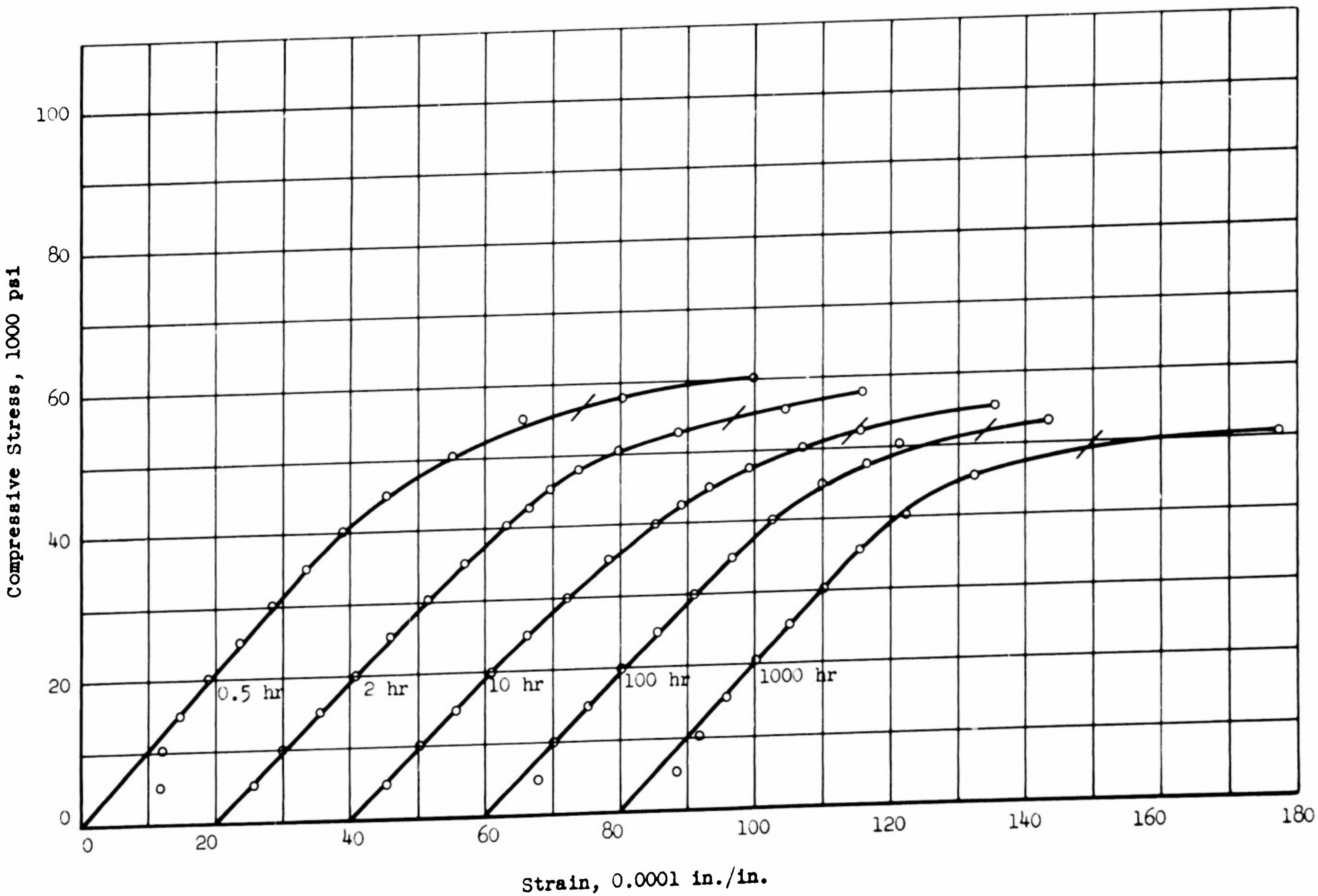

Fig. C-9 COMPRESSIVE STRESS-STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 300°F

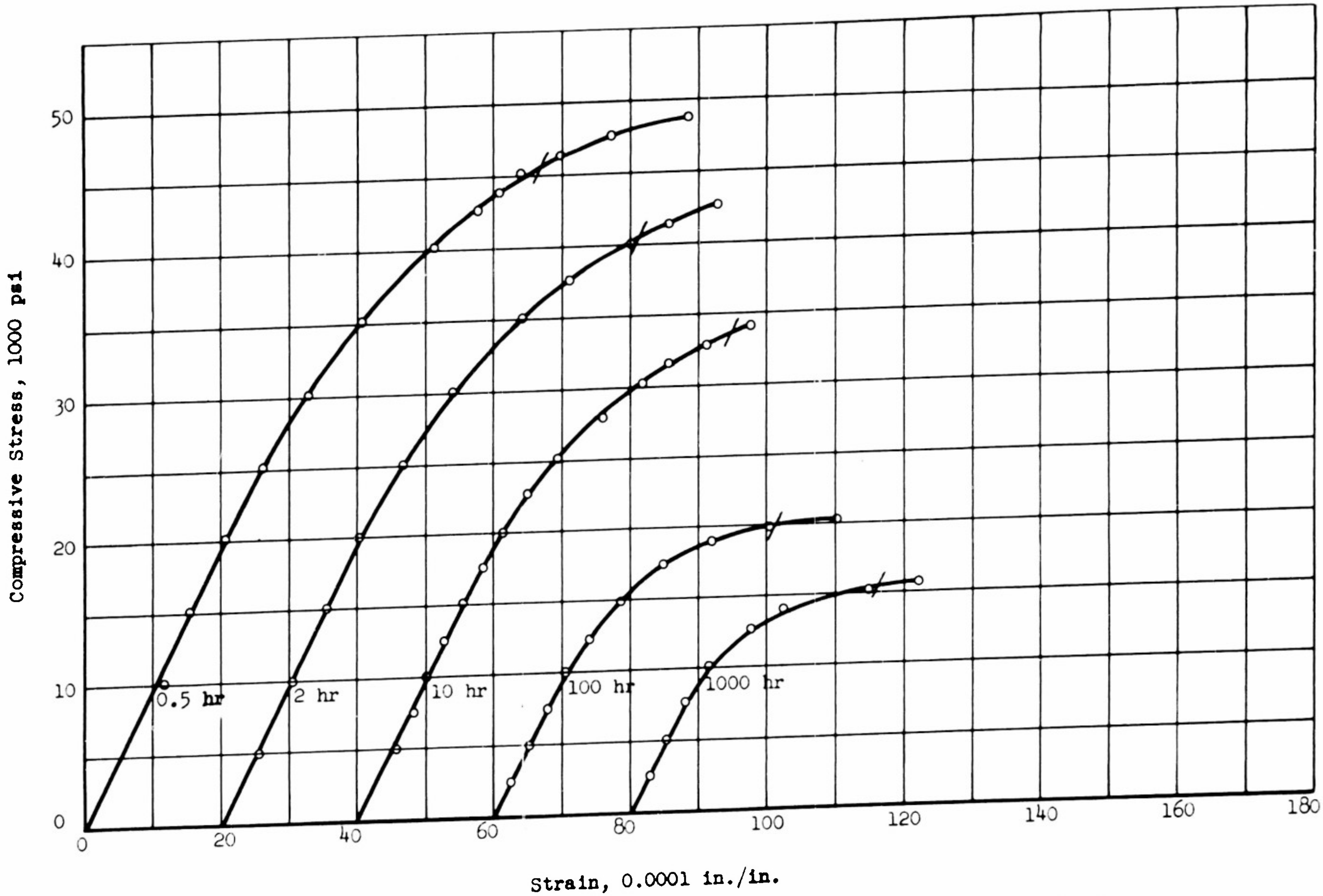

Fig. C-10 COMPRESSIVE STRESS-STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 400°F

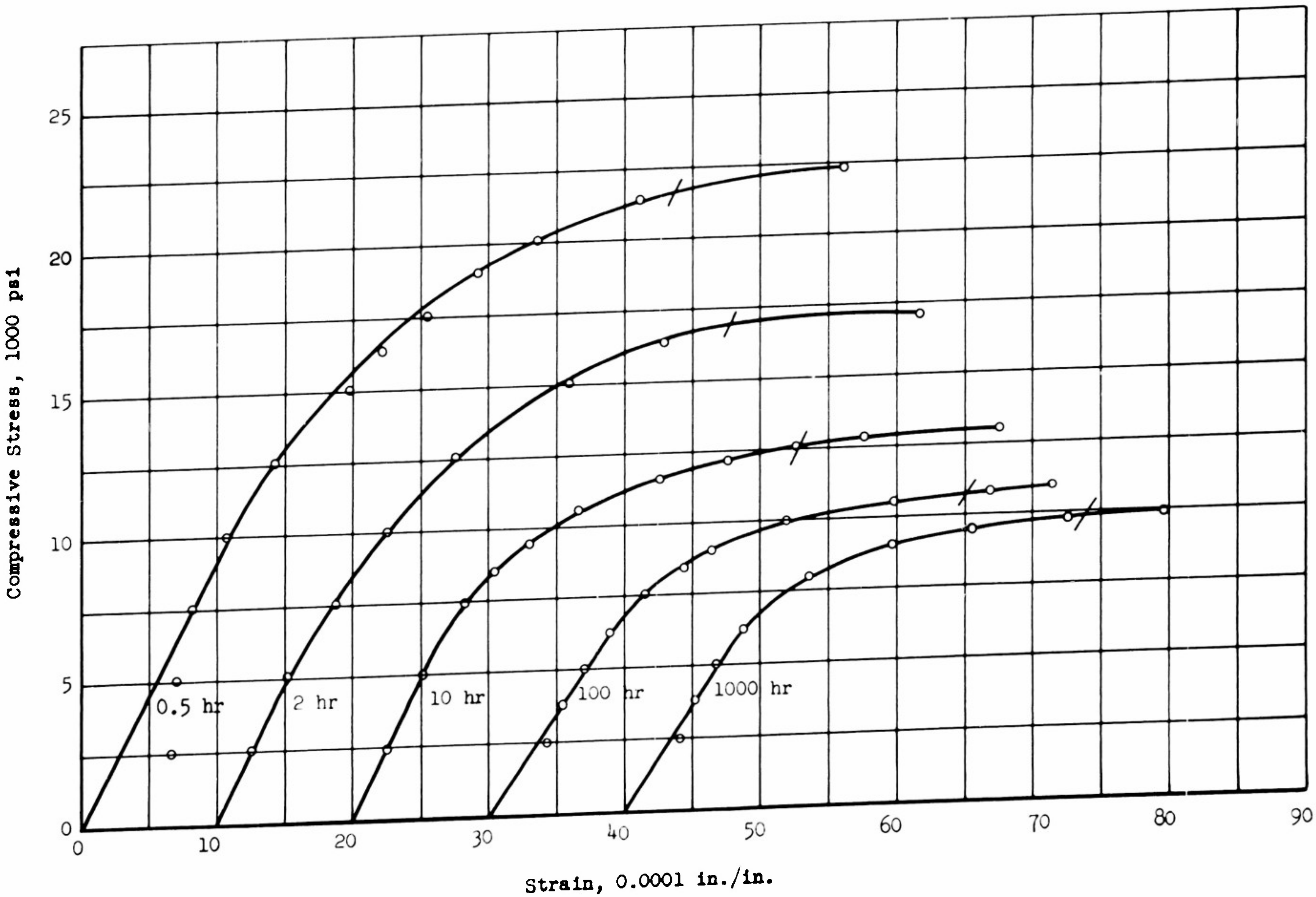

Fig. C-11 COMPRESSIVE STRESS STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 500°F

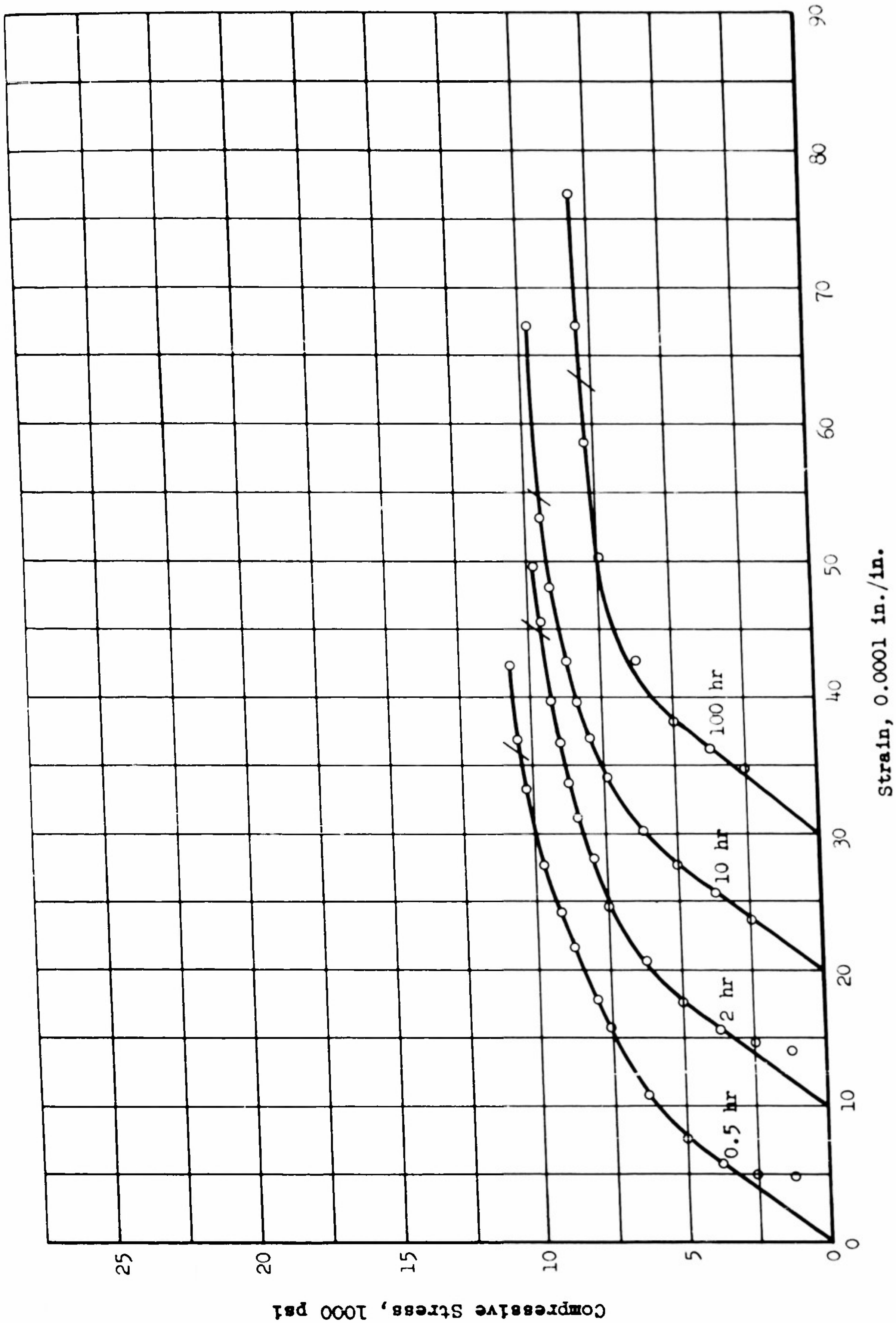

Fig. C-12 COMPRESSIVE STRESS-STRAIN CURVES FOR 14S-T6 ALUMINUM ALLOY AT 600°F

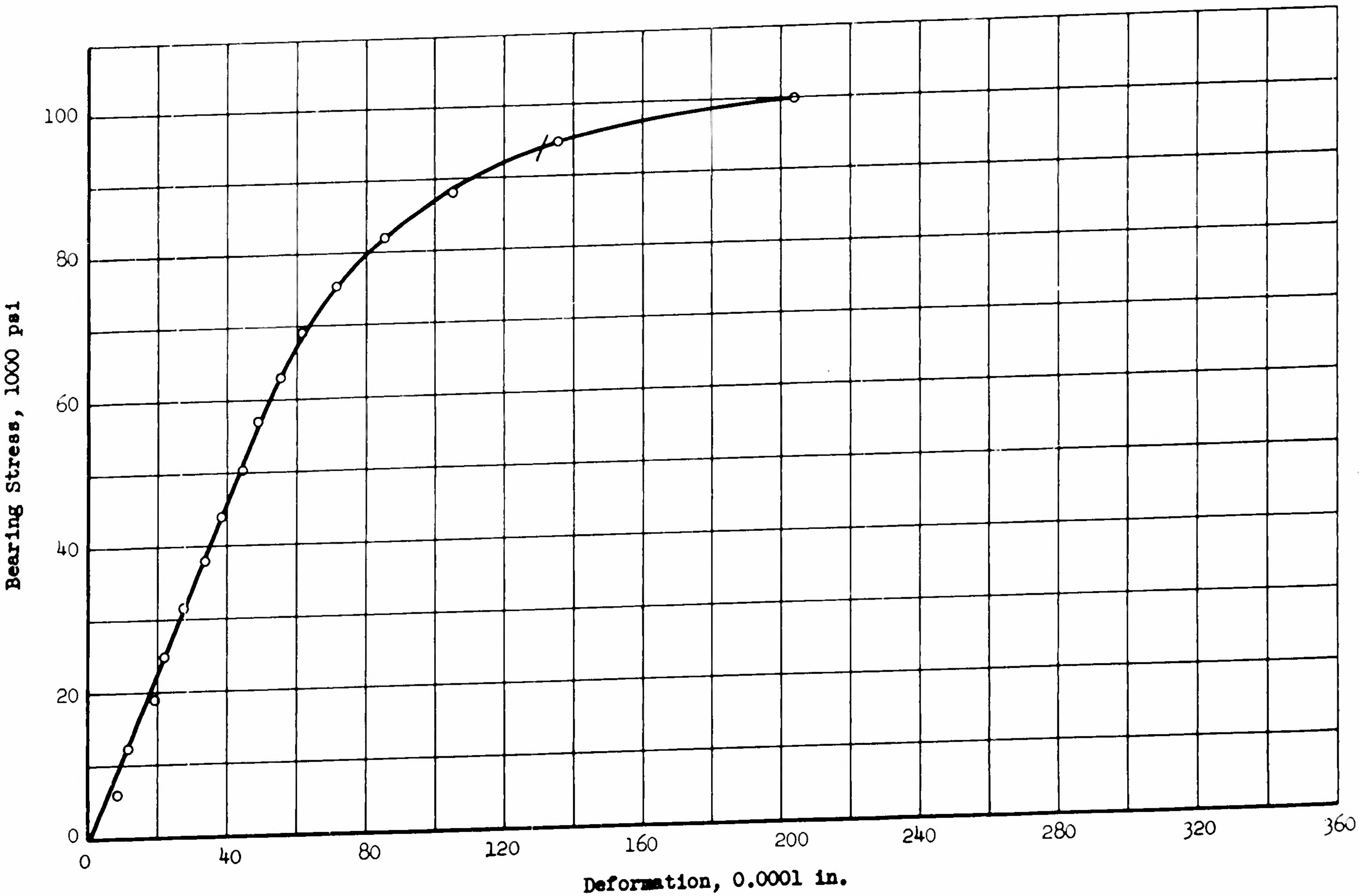

Fig. C-13 BEARING STRESS-DEFORMATION CURVE FOR 14S-T6 ALUMINUM ALLOY AT ROOM TEMPERATURE

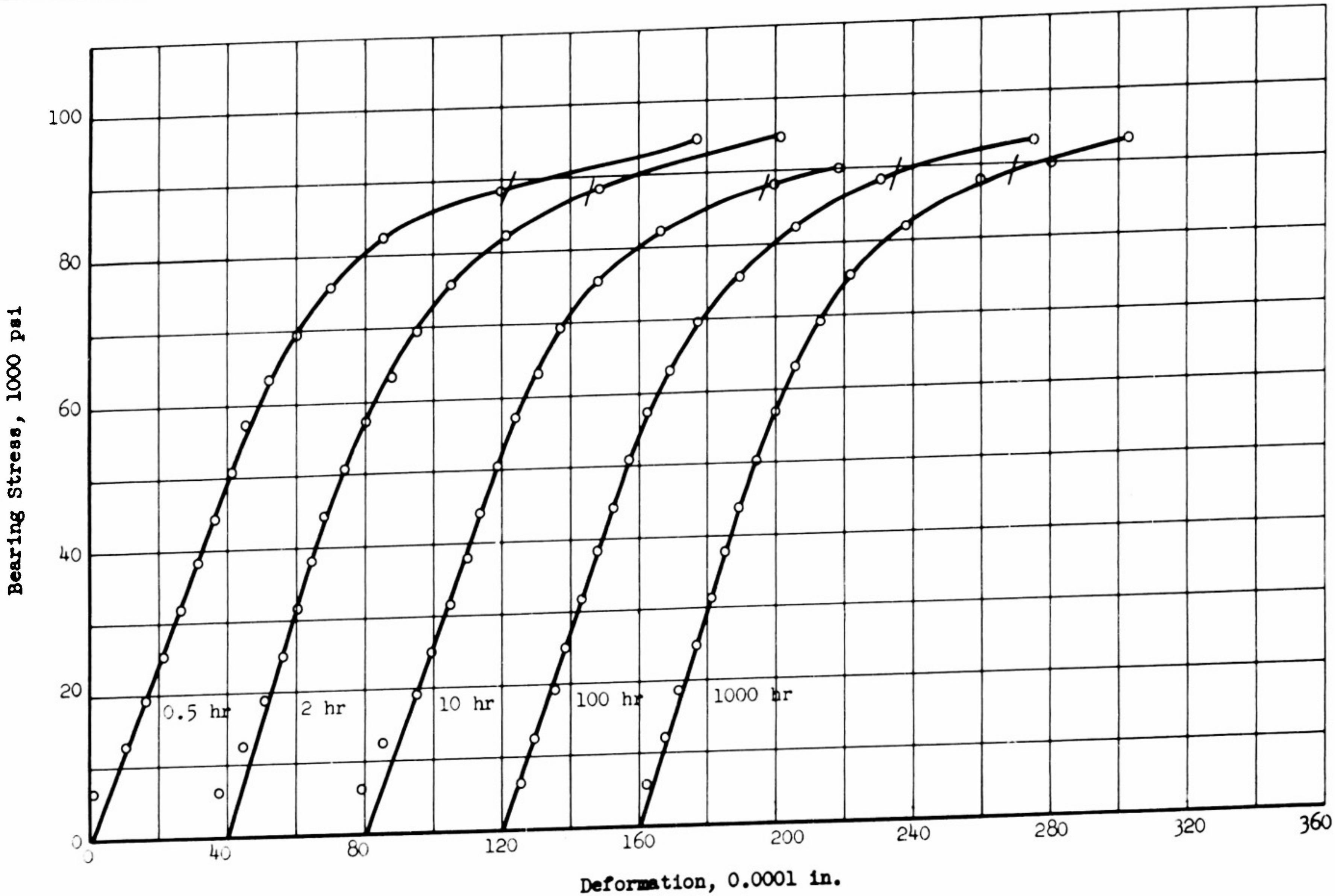

Fig. C-14 BEARING STRESS-DEFORMATION CURVES FOR 14S-T6 ALUMINUM ALLOY AT 200°F

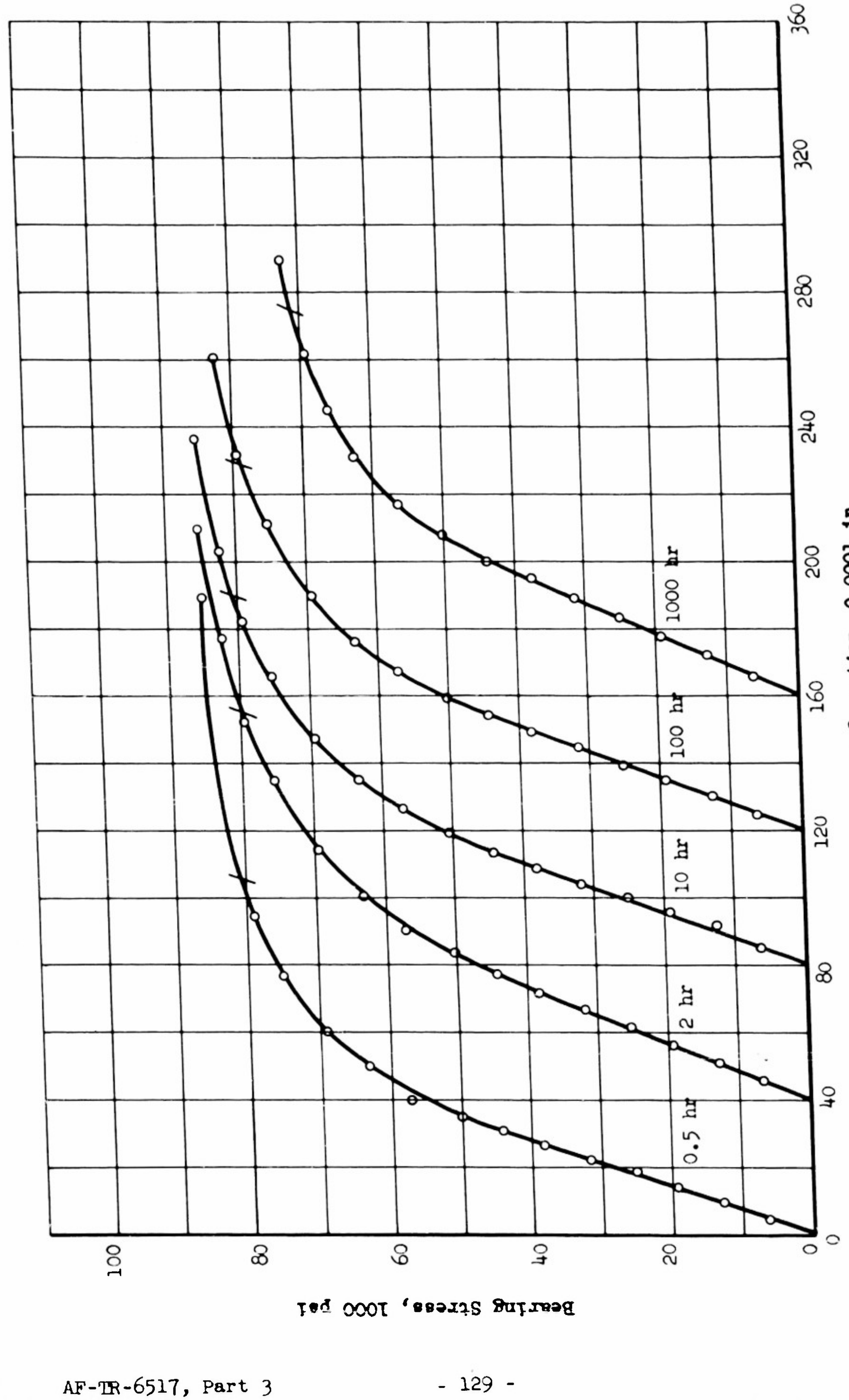

Fig. C-15 BEARING STRESS-DEFORMATION CURVES FOR 14S-T6 ALUMINUM ALLOY AT 300°F

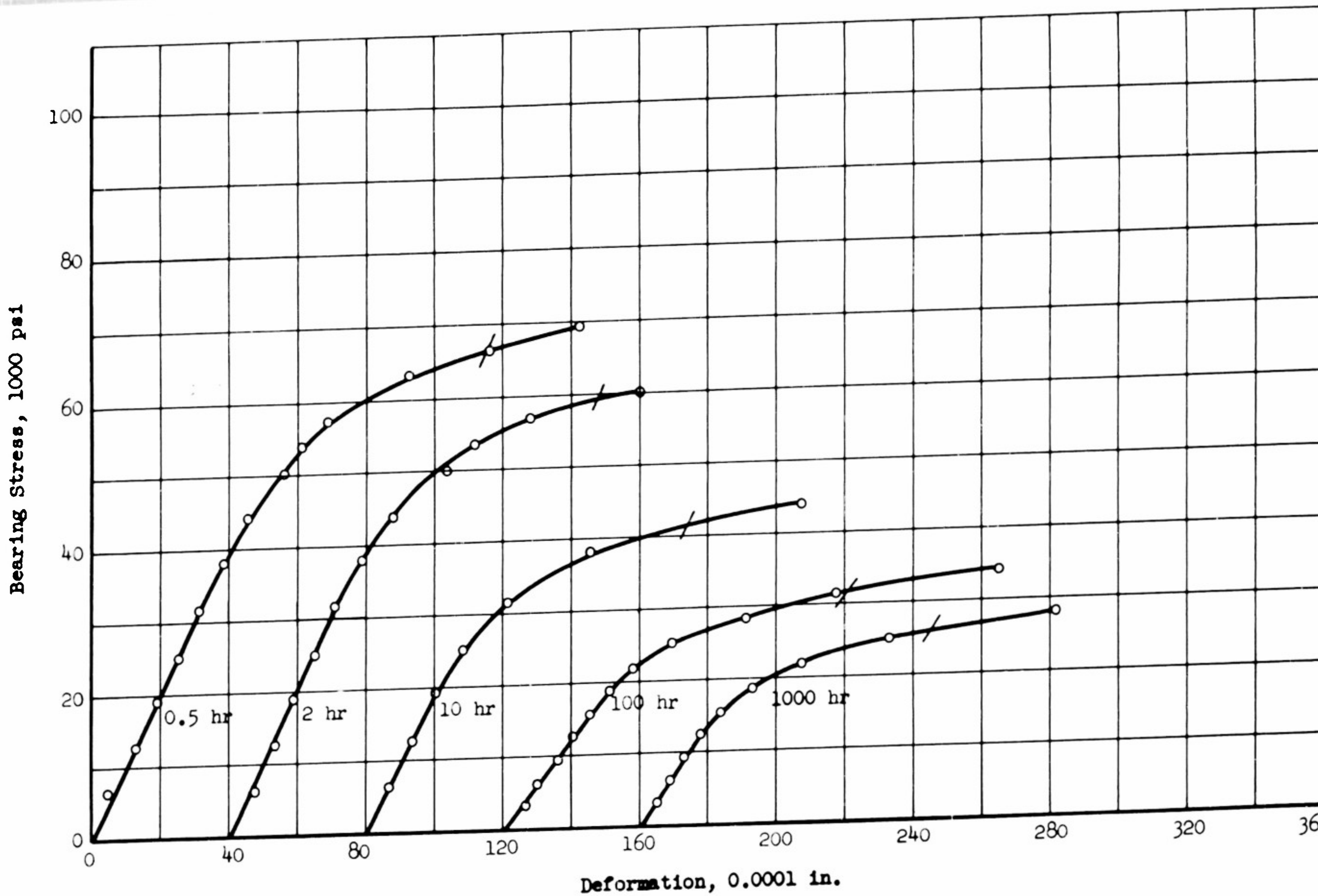

Fig. C-16 BEARING STRESS-DEFORMATION CURVES FOR 14S-T6 ALUMINUM ALLOY AT 400°F

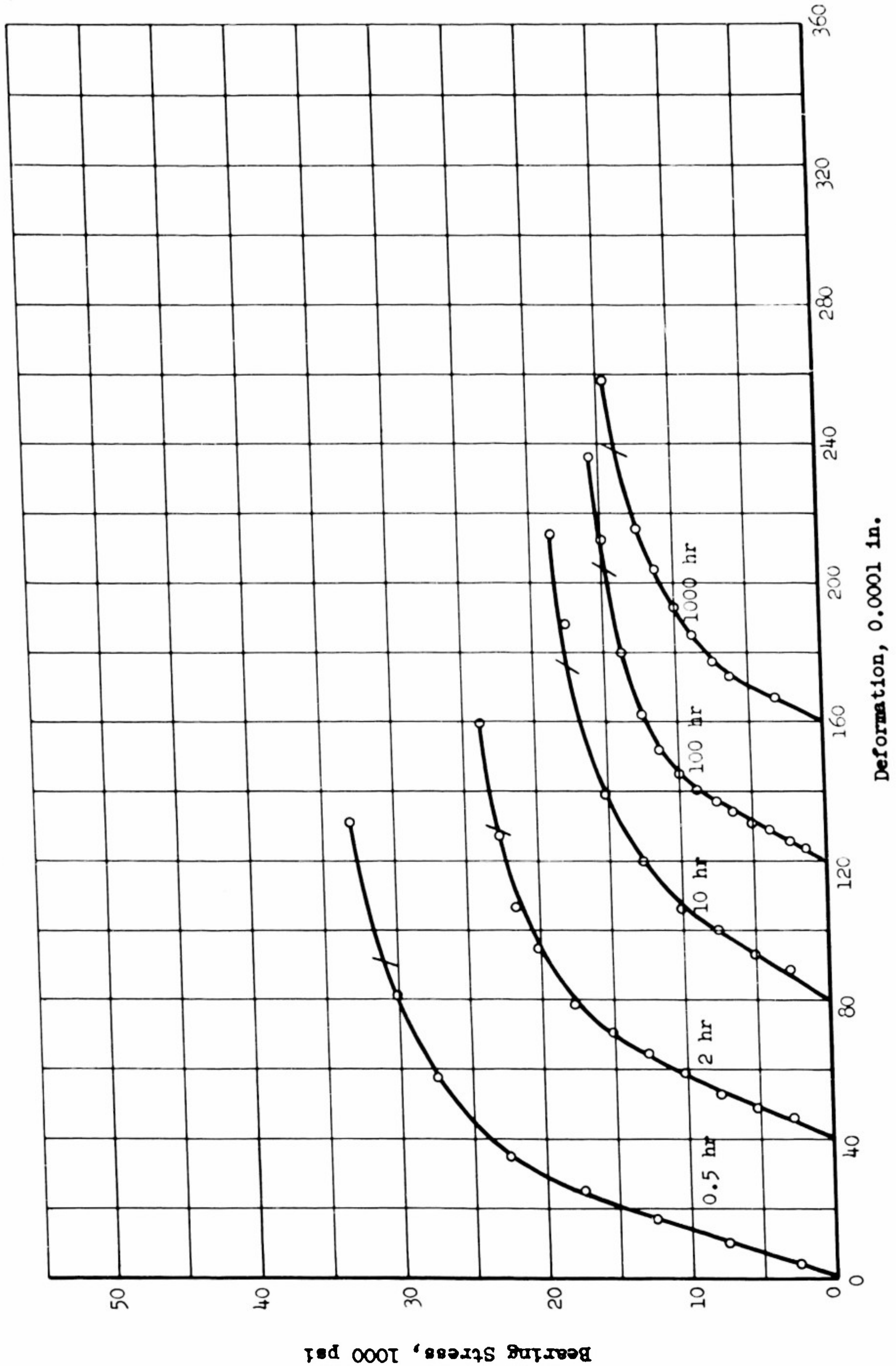

Fig. C-17 BEARING STRESS-DEFORMATION CURVES FOR 14S-T6 ALUMINUM ALLOY AT 500°F

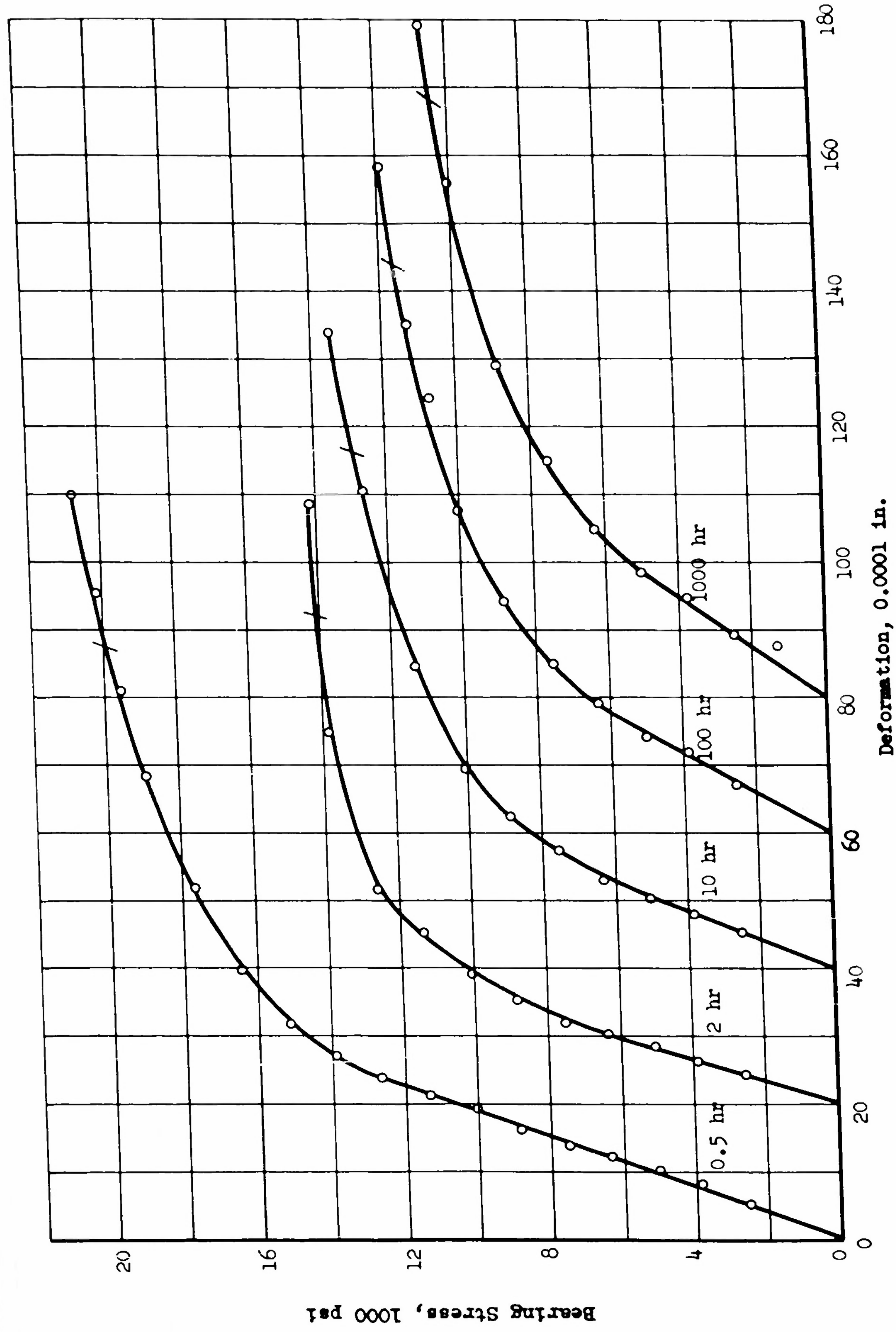

Fig. C-18 BEARING STRESS-DEFORMATION CURVES FOR 14S-T6 ALUMINUM ALLOY AT 600°F

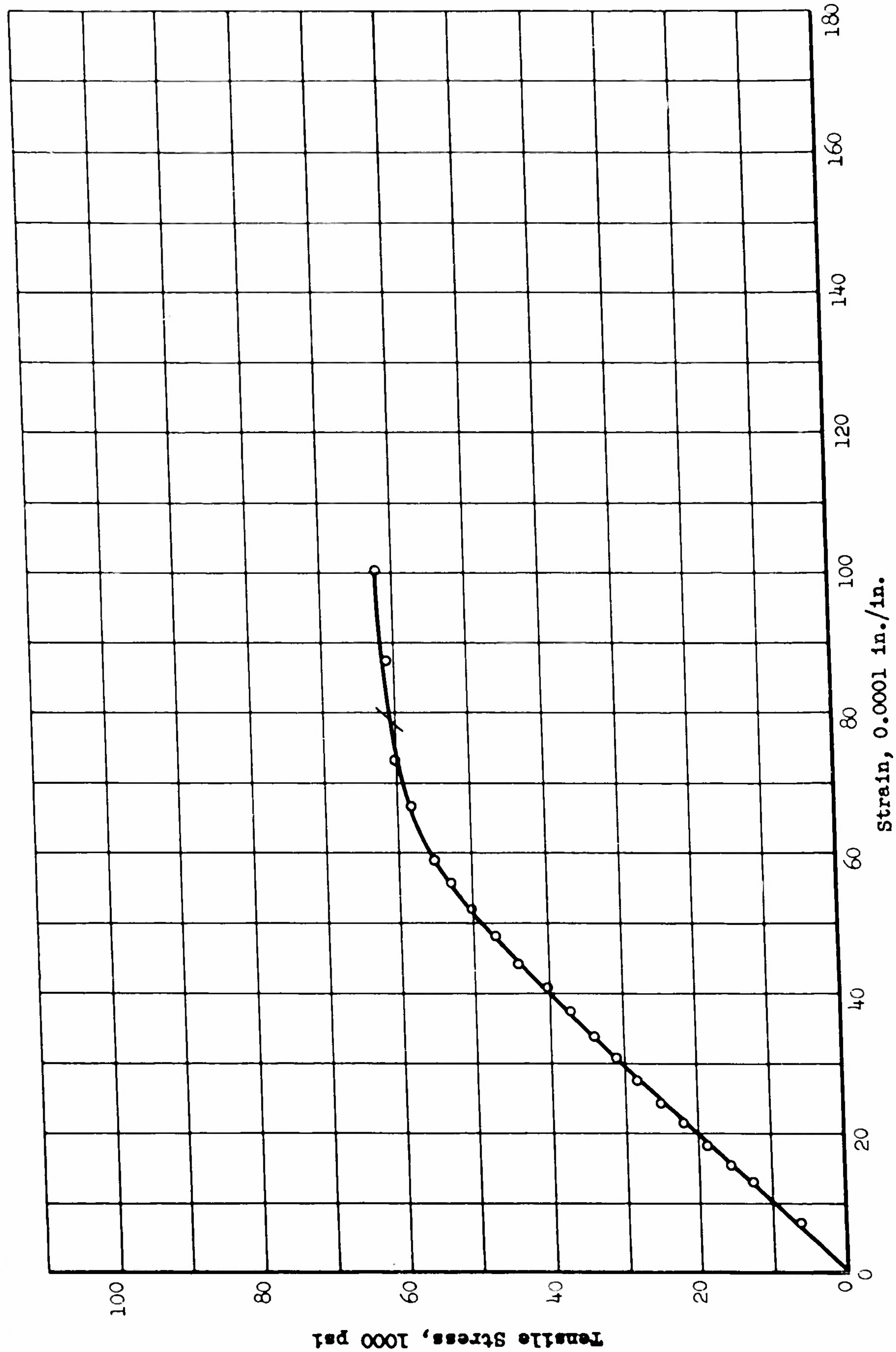

Fig. C-19 TENSILE STRESS-STRAIN CURVE FOR 24S-T81 ALUMINUM ALLOY AT ROOM TEMPERATURE

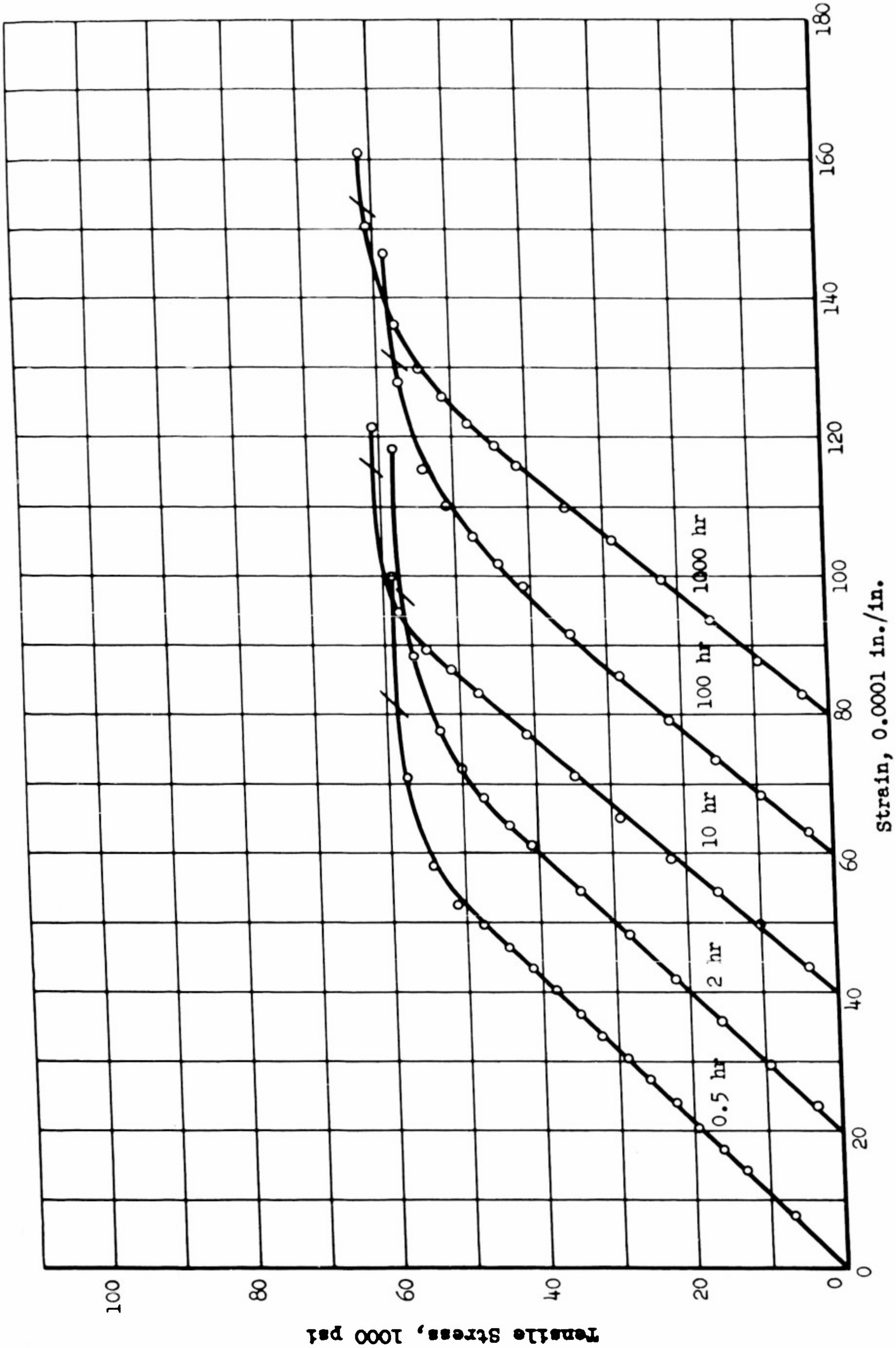

Fig. C-20 TENSILE STRESS-STRAIN CURVES FOR 24S-T81 ALUMINUM ALLOY AT 200°F

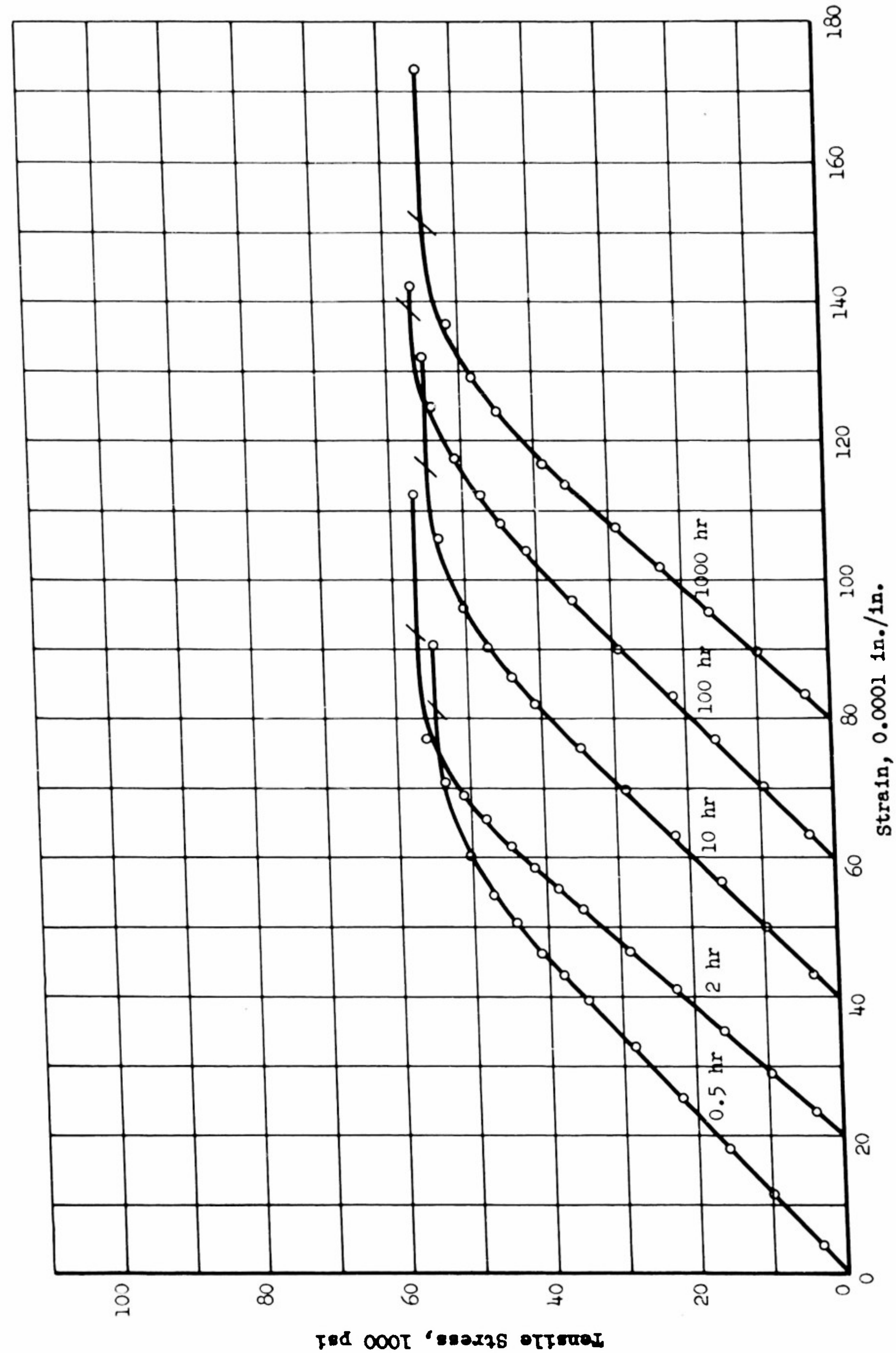

Fig. C-21 TENSILE STRESS-STRAIN CURVES FOR 24S-T81 ALUMINIUM ALLOY AT 300°F

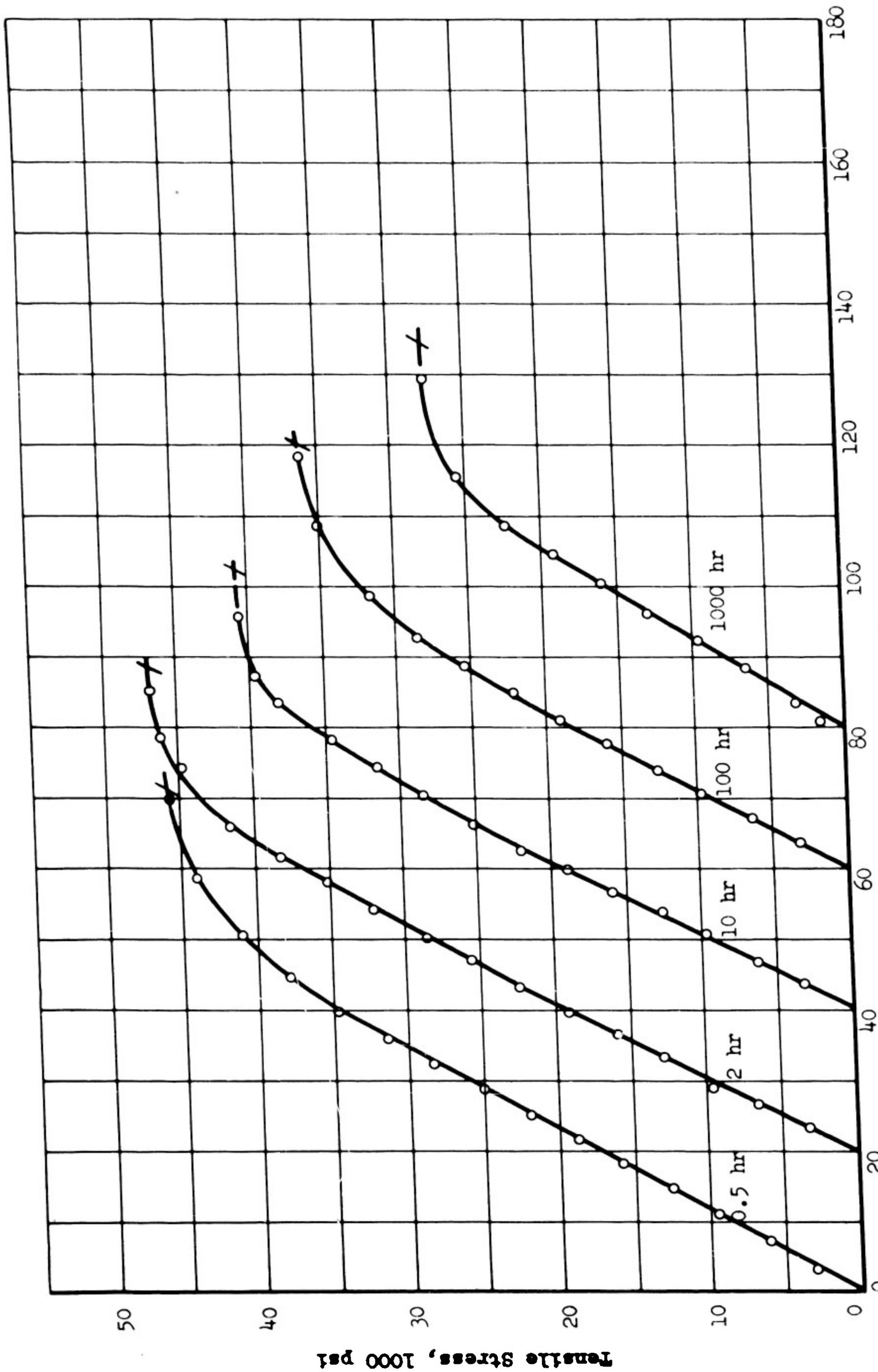

Fig. C-22 TENSILE STRESS-STRAIN CURVES FOR 24S-T81 ALUMINUM ALLOY AT 400°F

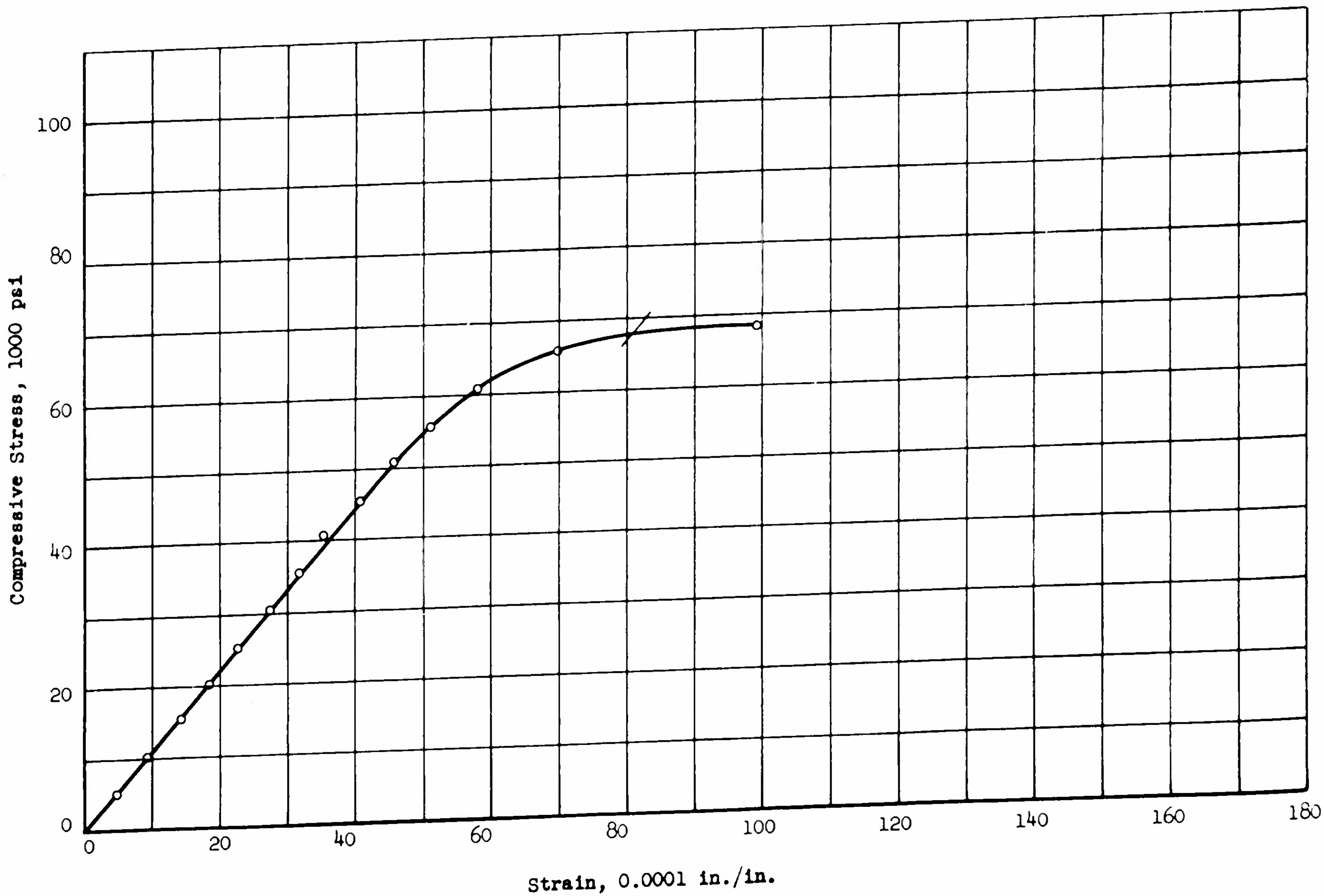

Fig. C-23 COMPRESSIVE STRESS-STRAIN CURVE FOR 24S-T81 ALUMINUM ALLOY AT ROOM TEMPERATURE

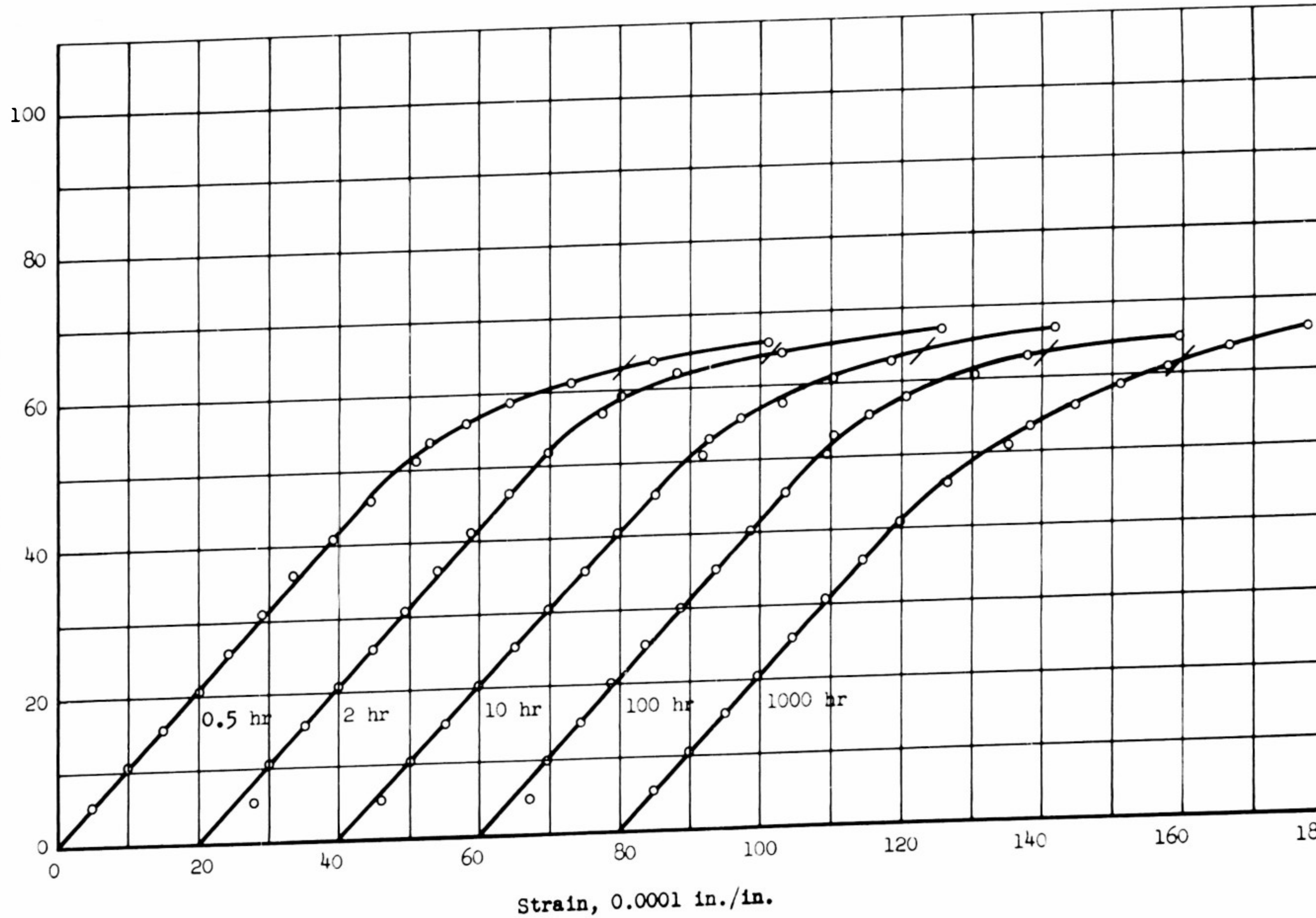

Fig. C-24 COMPRESSIVE STRESS-STRAIN CURVES FOR 24S-T81 ALUMINUM ALLOY AT 200°F

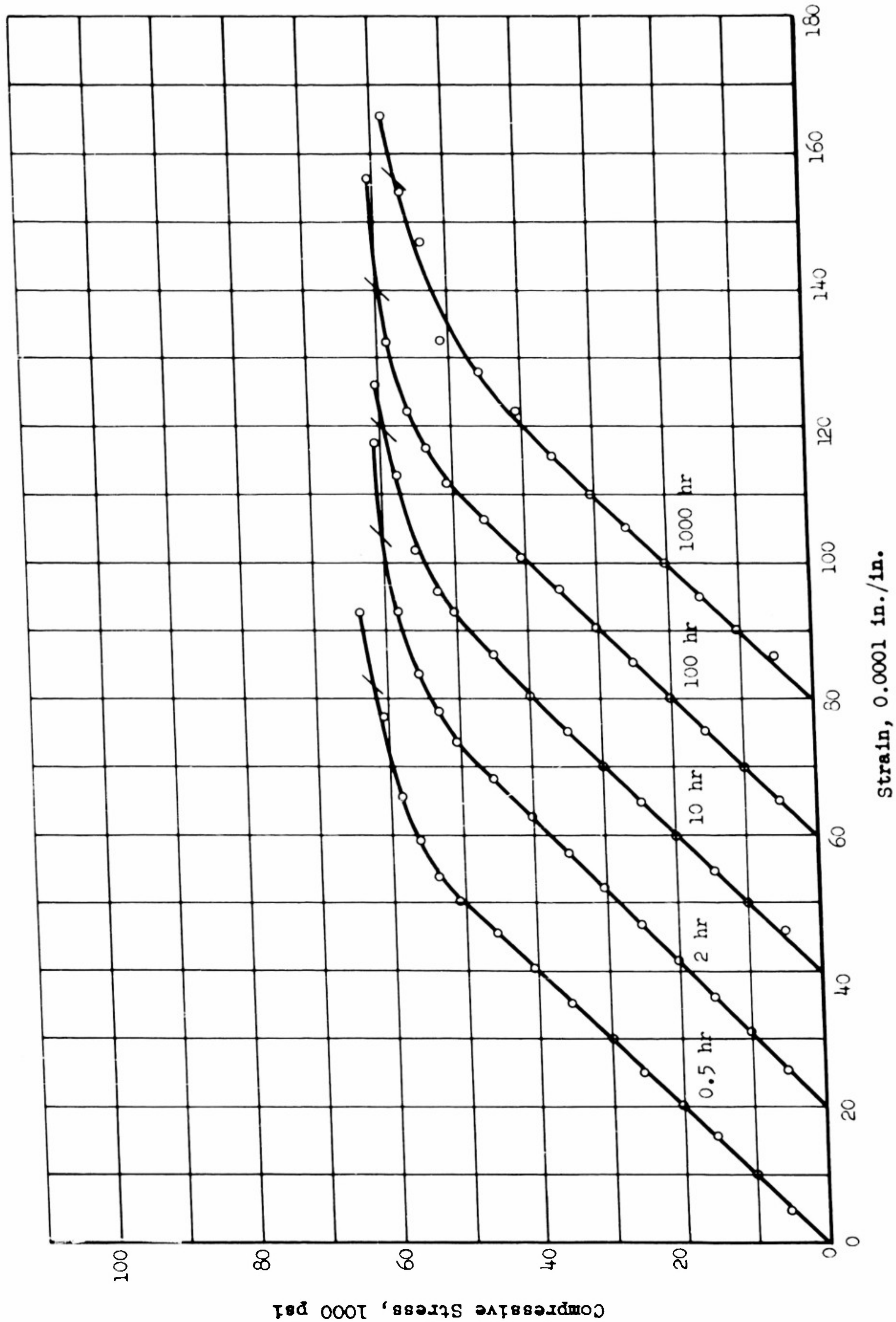

Fig. C-25 COMPRESSIVE STRESS-STRAIN CURVES FOR 24S-T81 ALUMINUM ALLOY AT 300°F

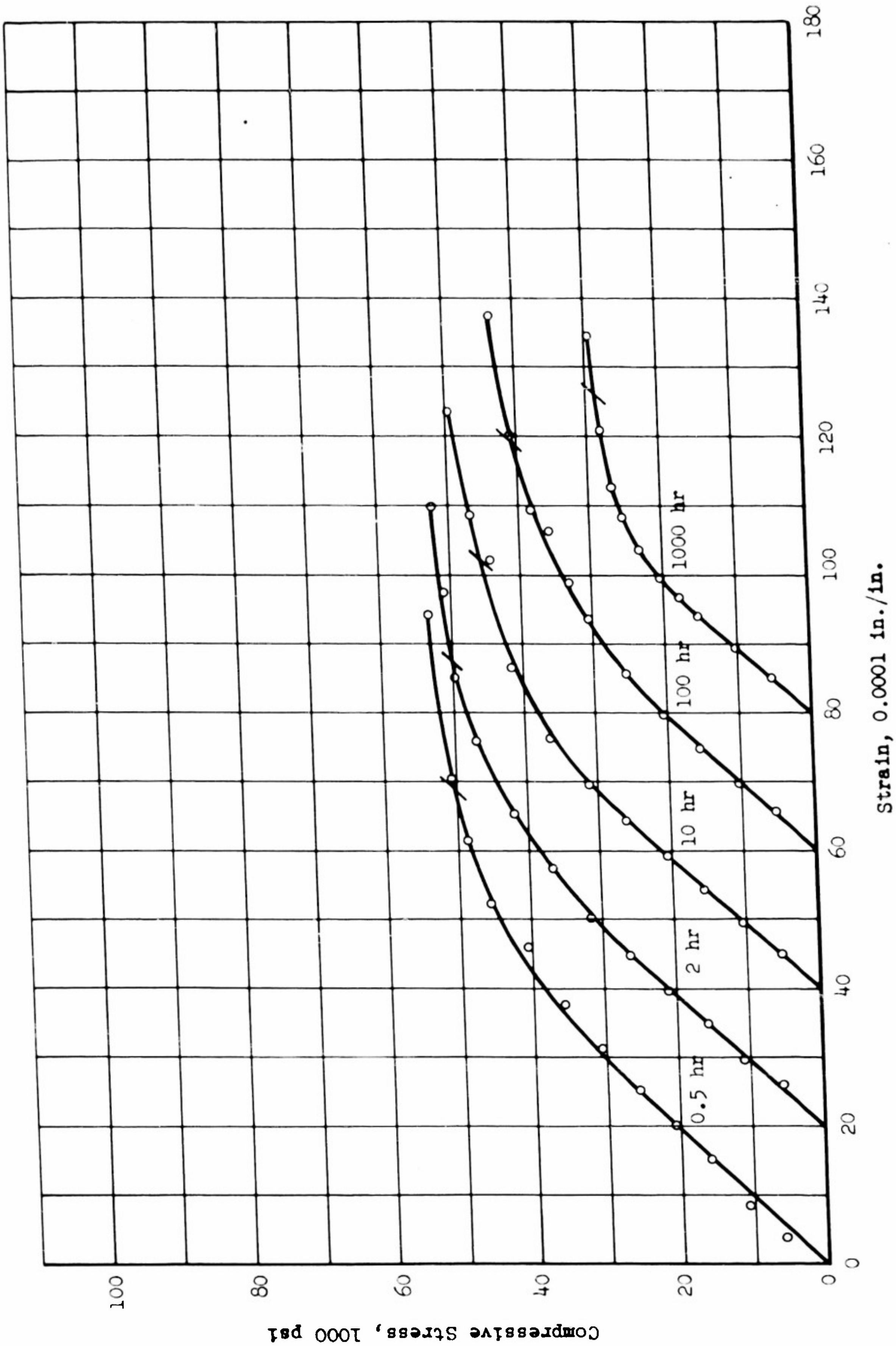

Fig. 26 COMPRESSIVE STRESS-STRAIN CURVES FOR 24S-T81 ALUMINUM ALLOY AT 400°F

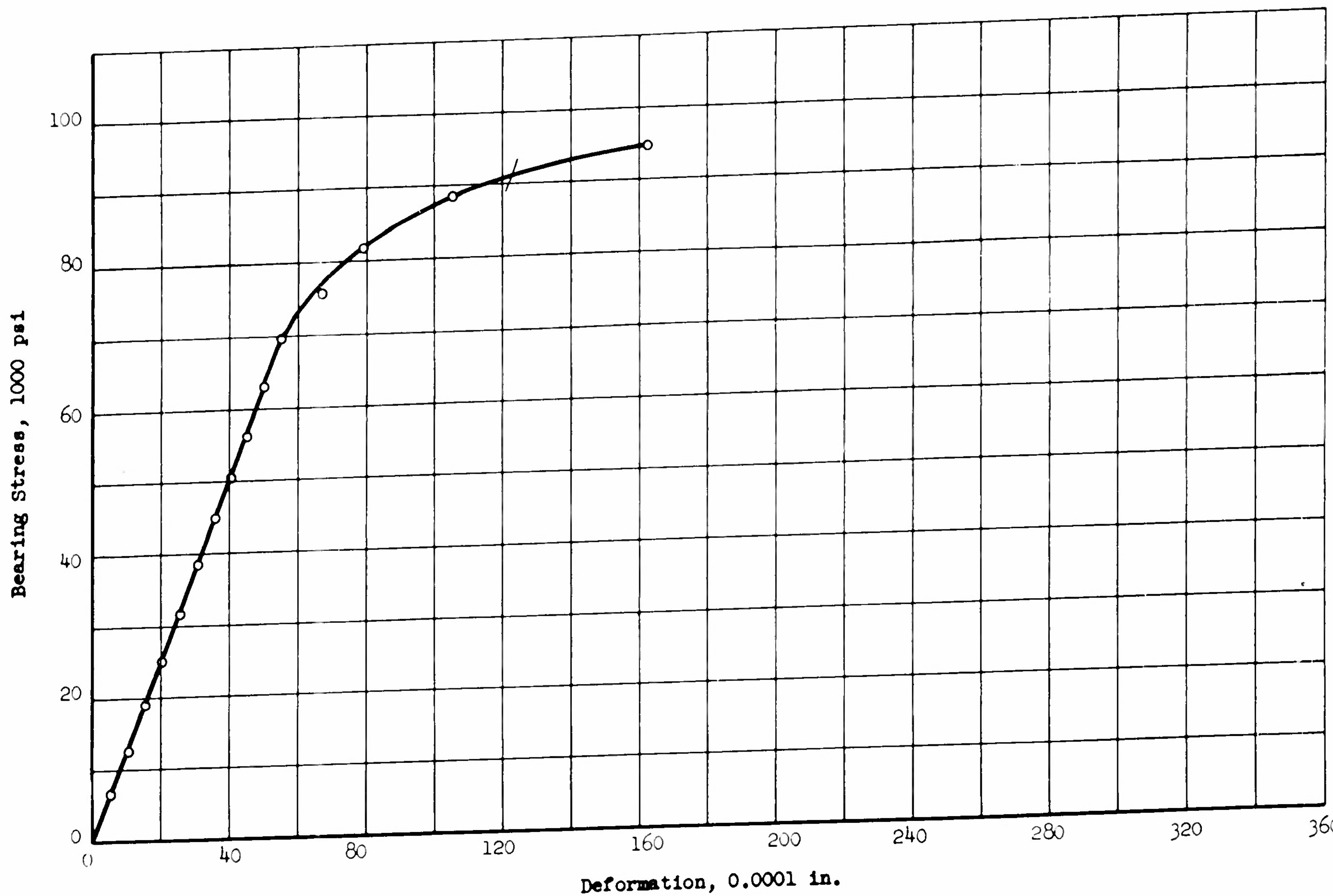

Fig. C-27 BEARING STRESS-DEFORMATION CURVE FOR 24S-T81 ALUMINUM ALLOY AT ROOM TEMPERATURE

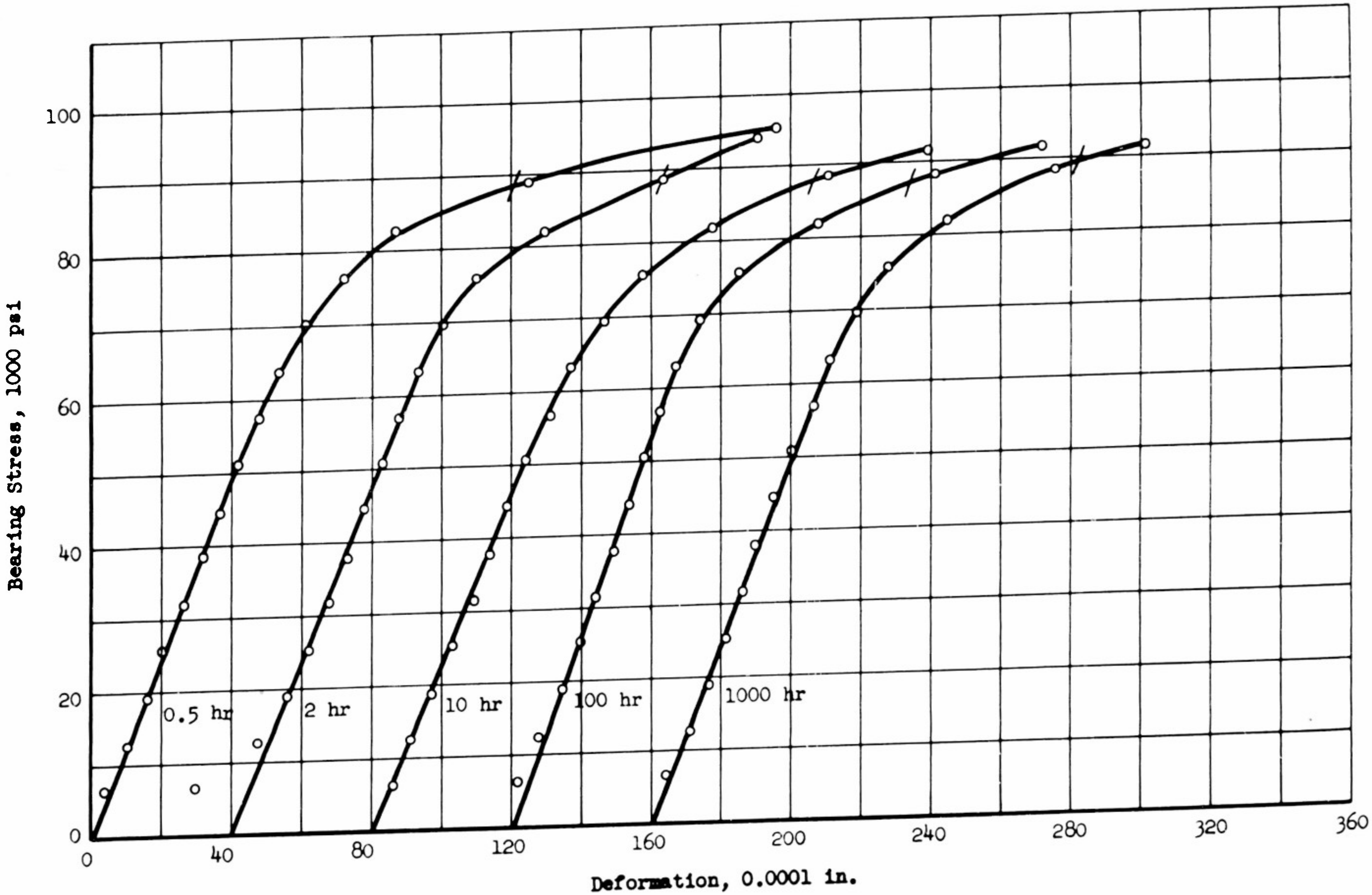

Fig. C-28 BEARING STRESS-DEFORMATION CURVES FOR 24S-T81 ALUMINUM ALLOY AT 200°F

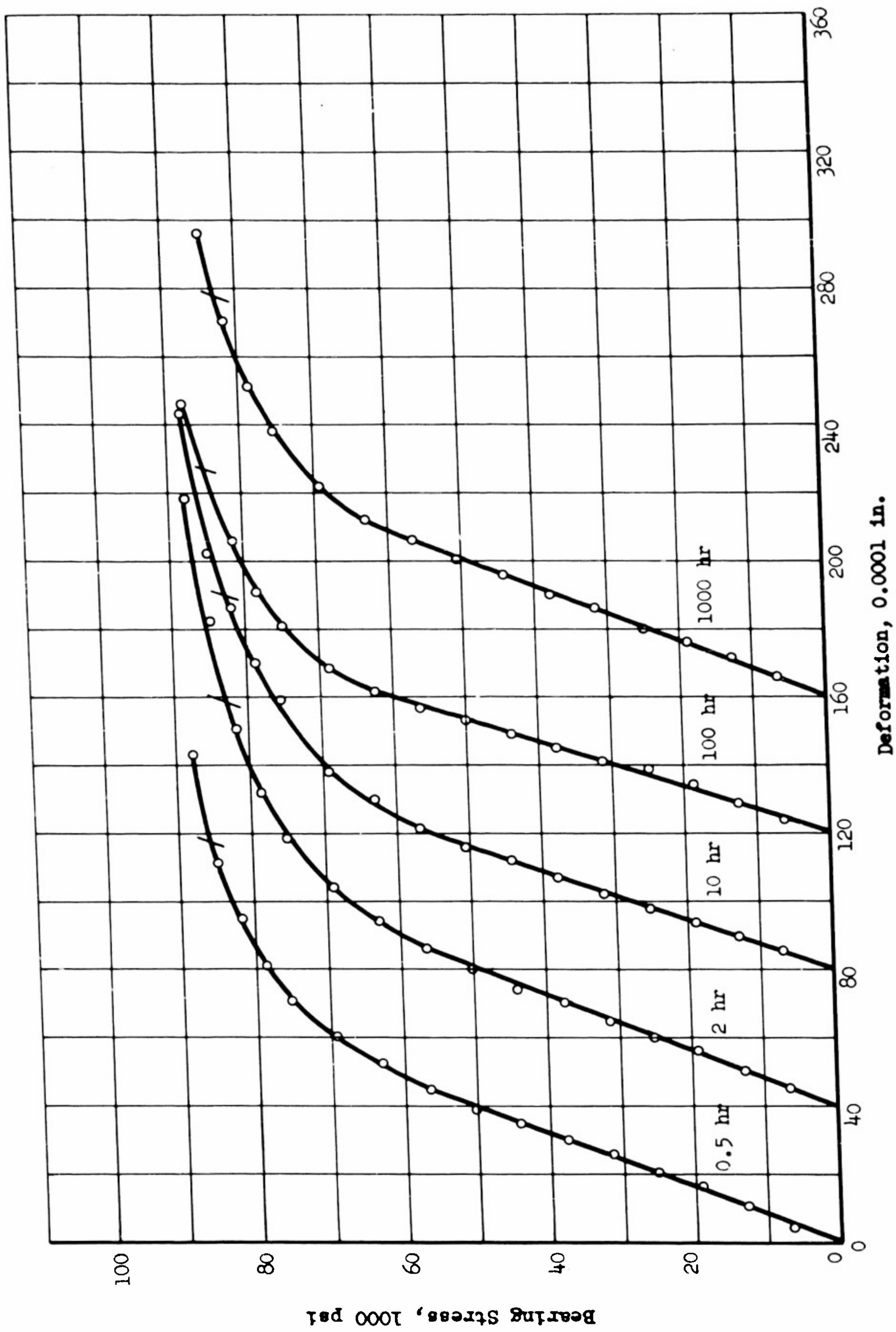

Fig. C-29 BEARING STRESS-DEFORMATION CURVES FOR 24S-T81 ALUMINUM ALLOY AT 300°F

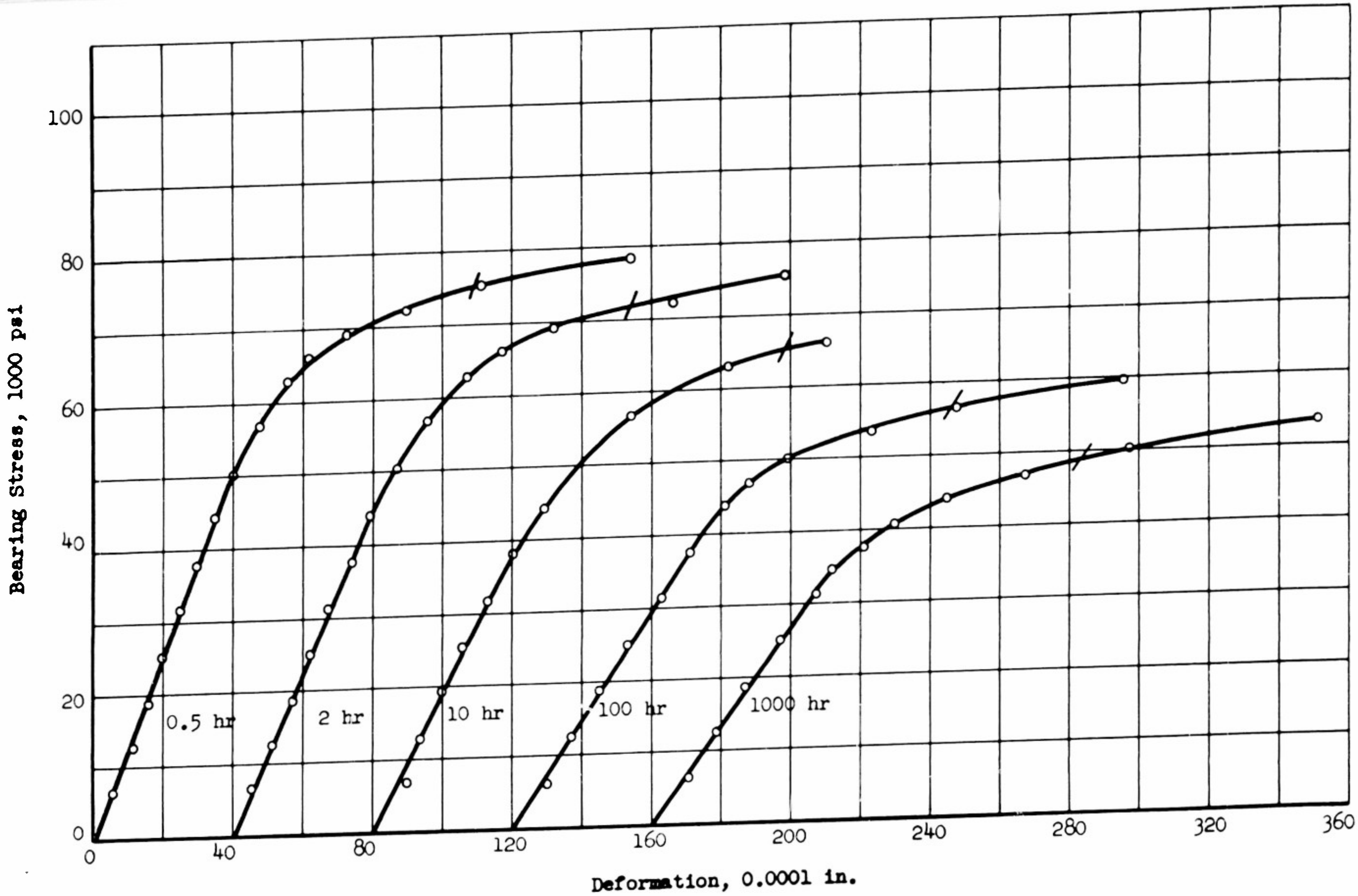

Fig. C-30 BEARING STRESS-DEFORMATION CURVES FOR 24S-T81 ALUMINUM ALLOY AT 400°F

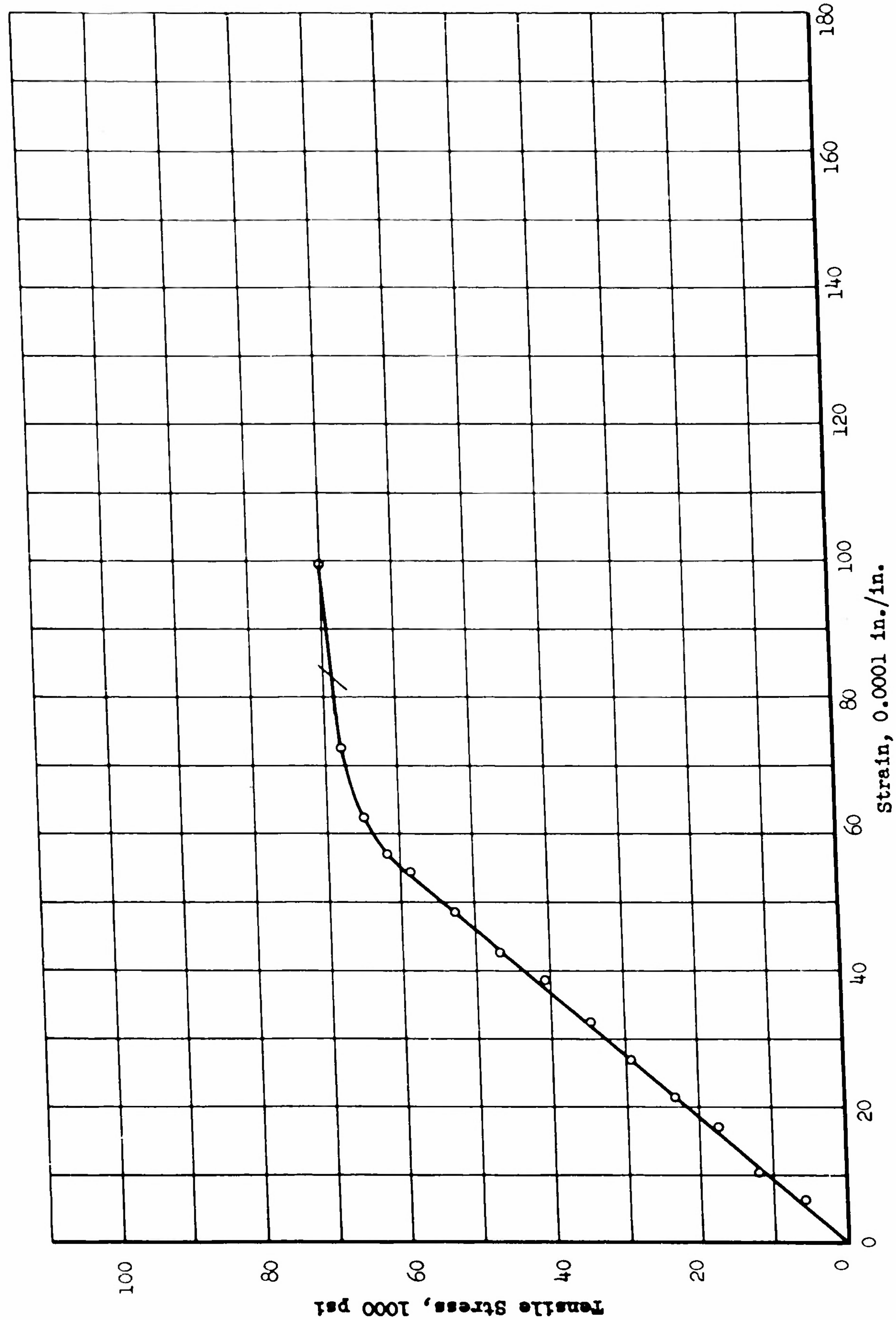

Fig. C-31 TENSILE STRESS-STRAIN CURVE FOR 24S-T86 ALUMINUM ALLOY AT ROOM TEMPERATURE

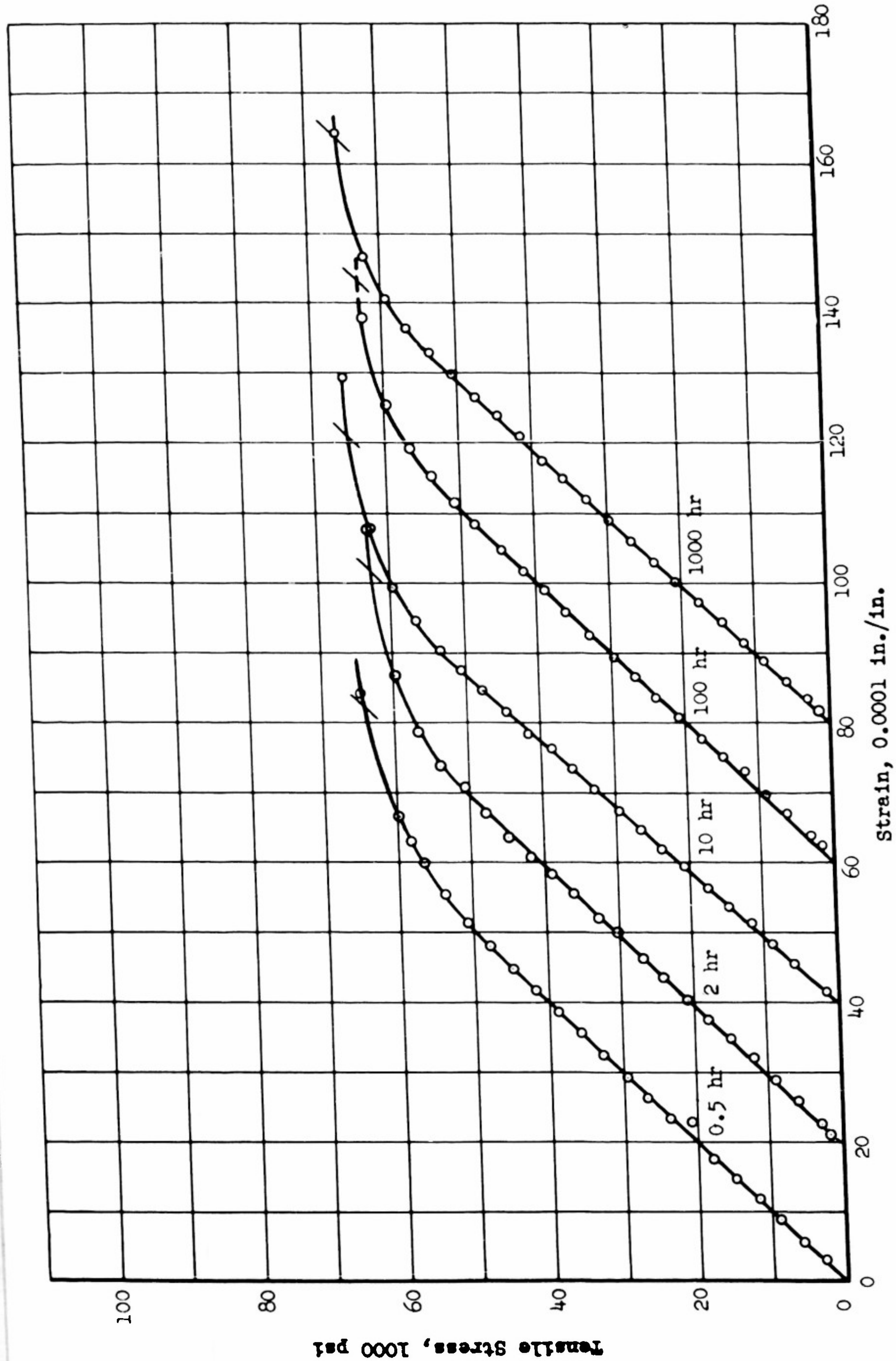

Fig. C-32 TENSILE STRESS-STRAIN CURVES FOR 24S-T86 ALUMINUM ALLOY AT 200°F

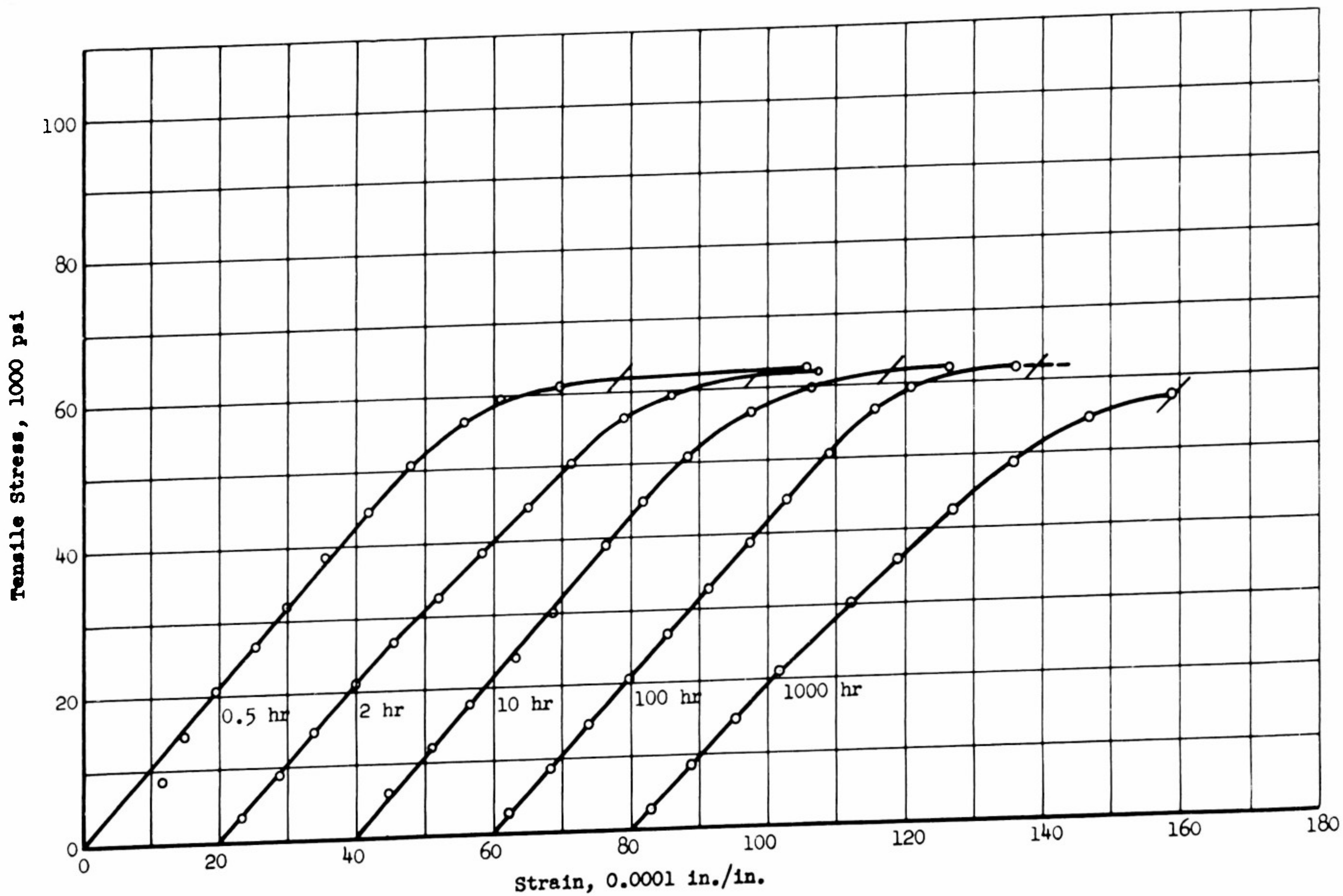

Fig. C-33 TENSILE STRESS-STRAIN CURVES FOR 24S-T86 ALUMINUM ALLOY AT 300°F

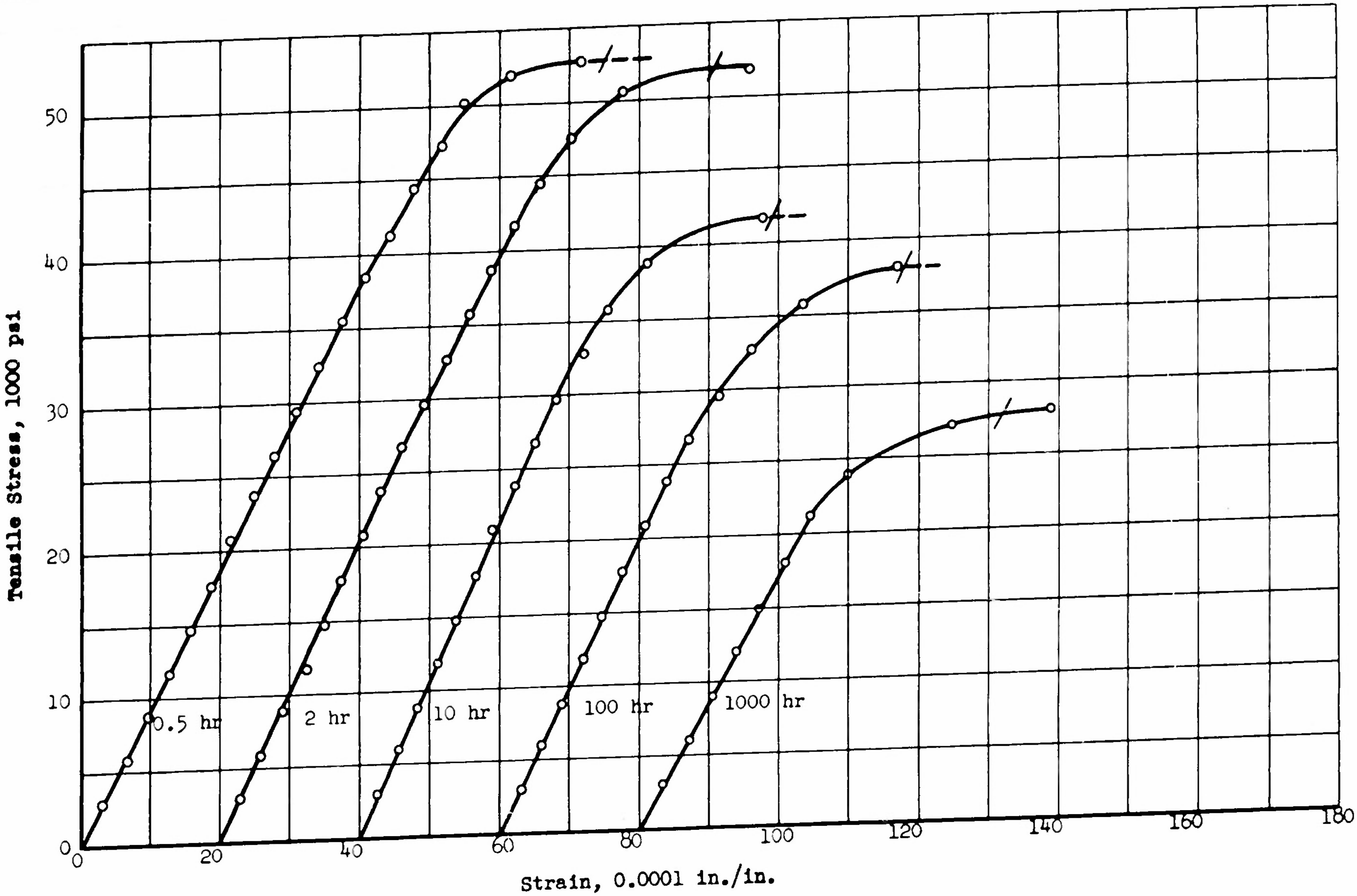

Fig. C-34 TENSILE STRESS-STRAIN CURVES FOR 24S-T86 ALUMINUM ALLOY AT 400°F

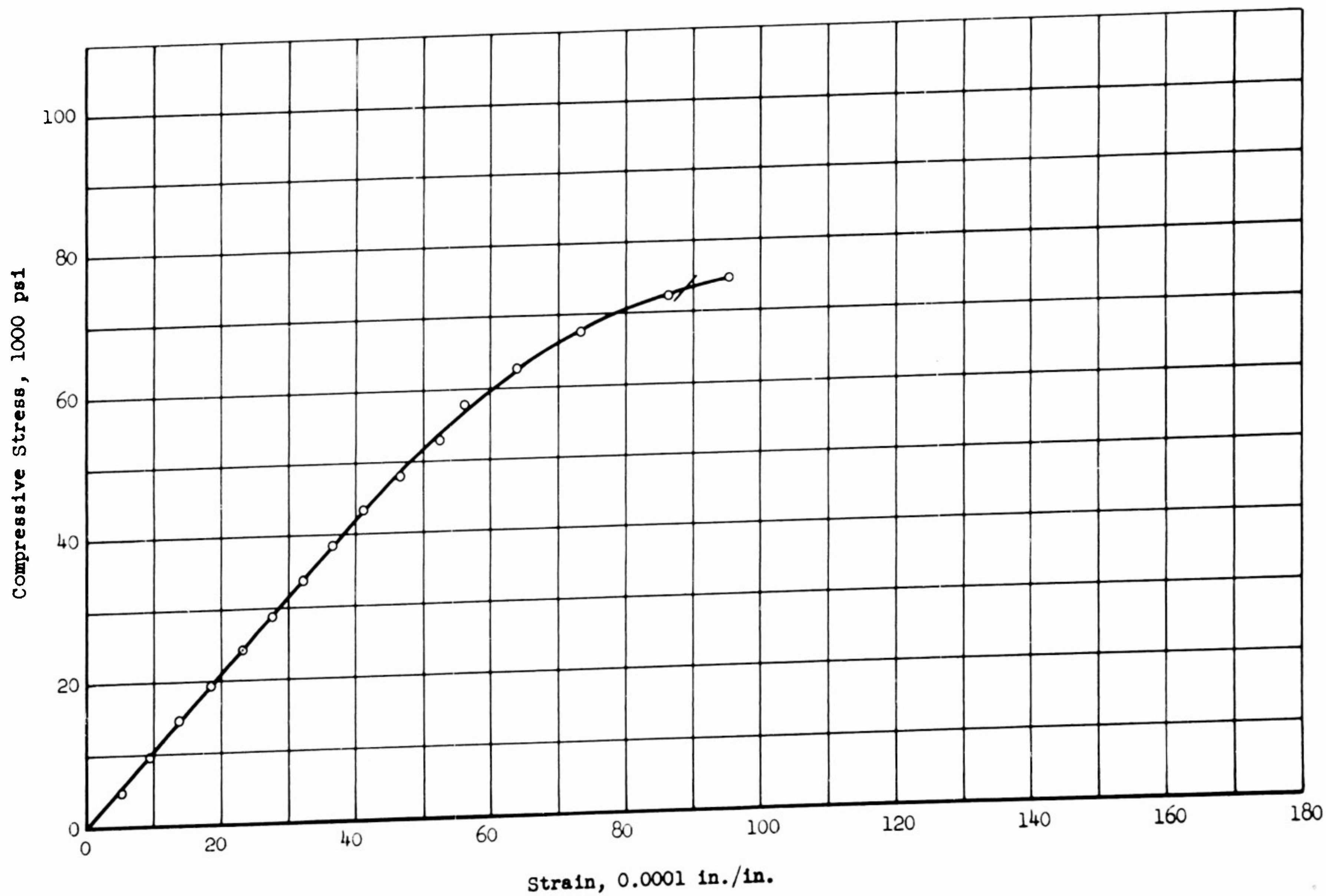

Fig. C-35 COMPRESSIVE STRESS-STRAIN CURVE FOR 24S-T86 ALUMINUM ALLOY AT ROOM TEMPERATURE

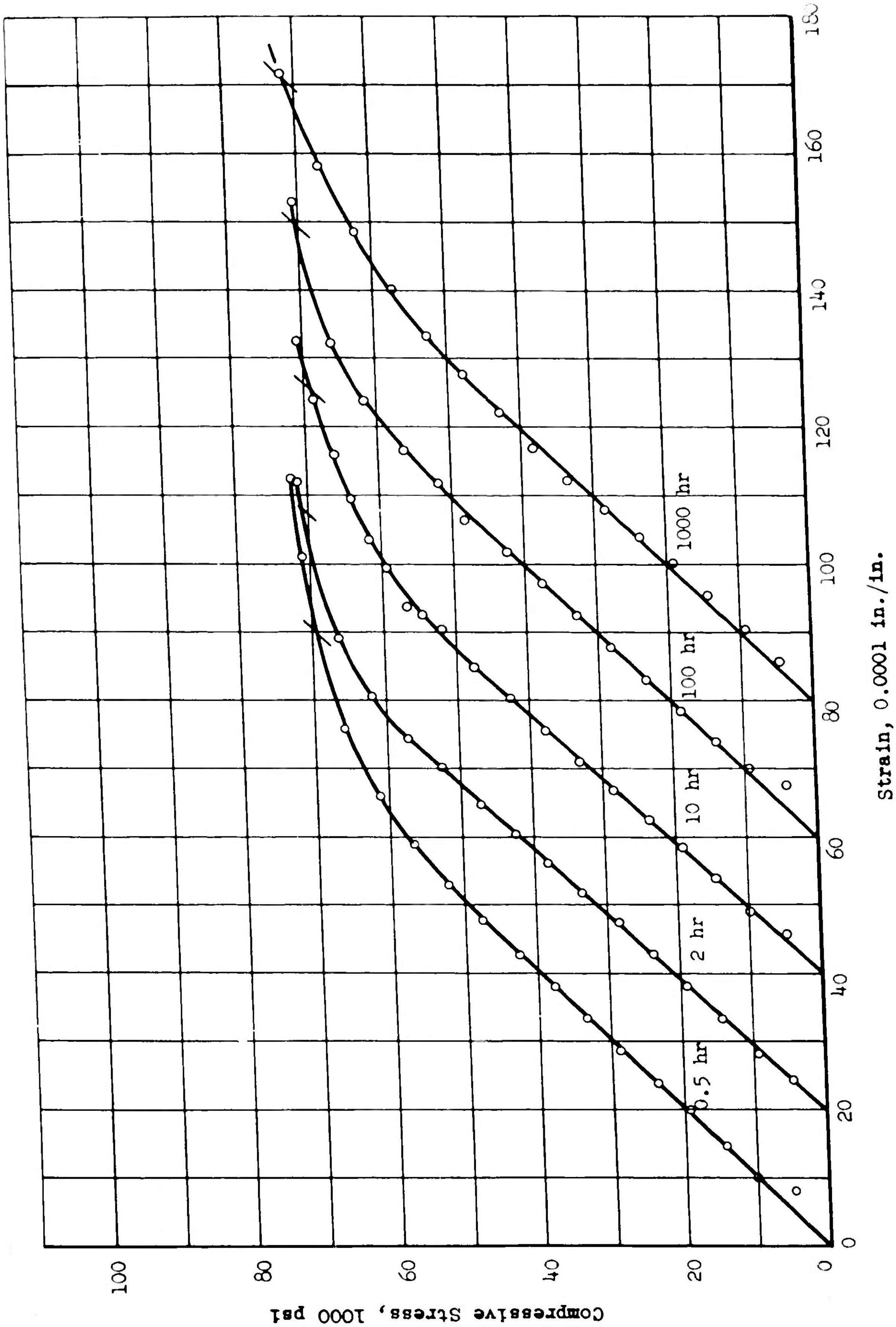

Fig. C-36 COMPRESSIVE STRESS-STRAIN CURVES FOR 24S-T86 ALUMINUM ALLOY AT 200°F

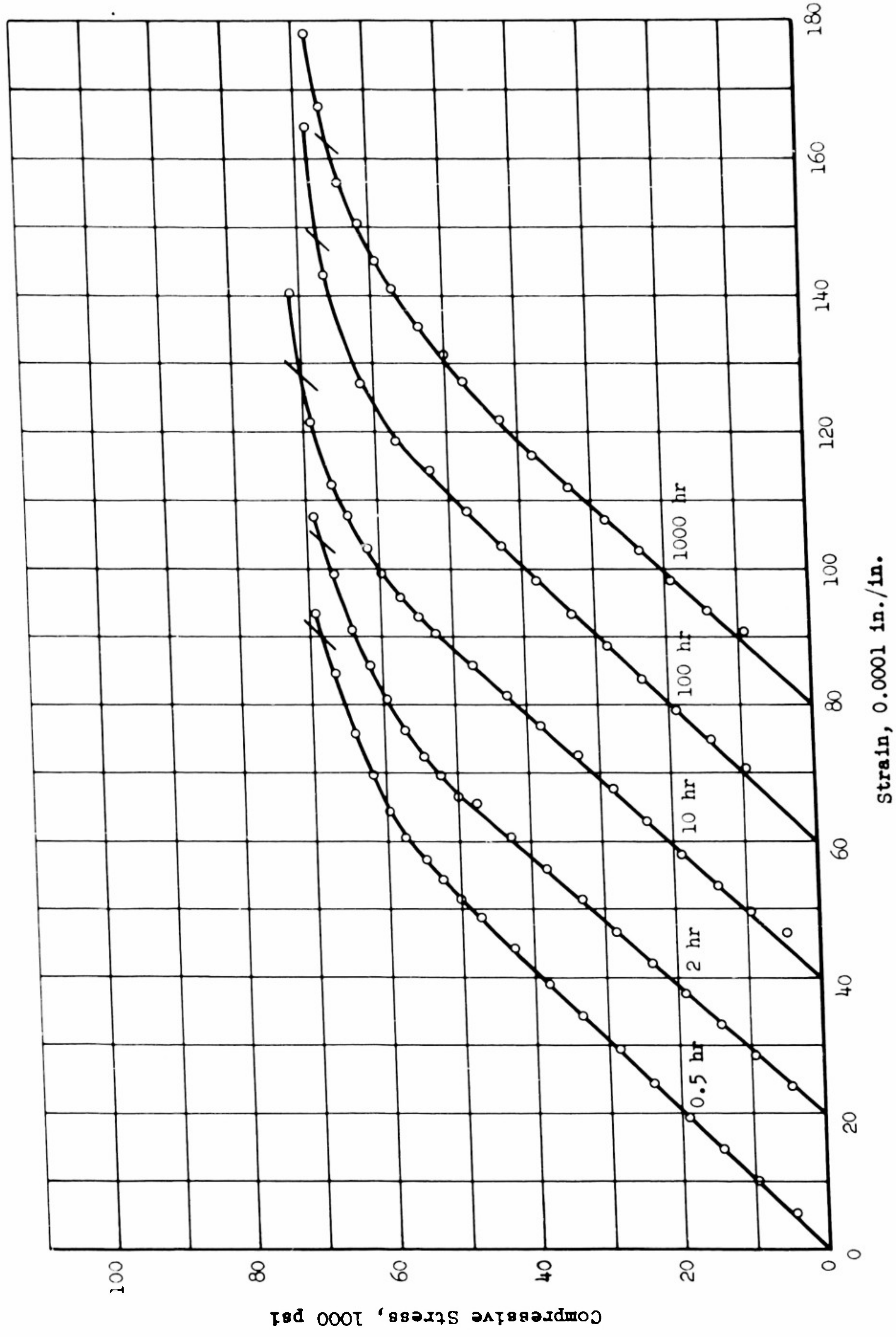

Fig. C-37 COMPRESSIVE STRESS-STRAIN CURVES FOR 24S-T86 ALUMINUM ALLOY AT 300°F

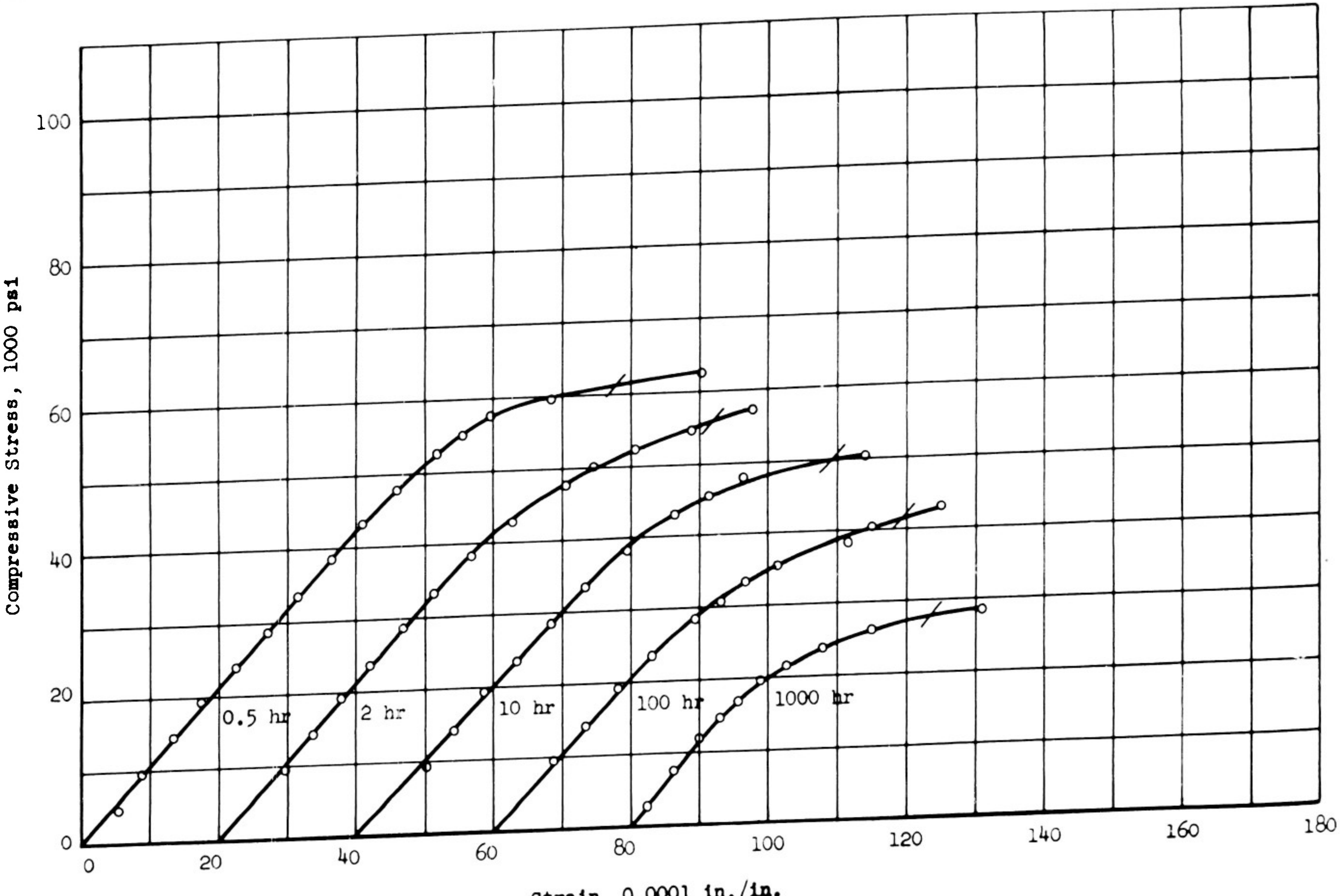

Fig. C-38 COMPRESSIVE STRESS-STRAIN CURVES FOR 24S-T86 ALUMINIUM ALLOY AT 400°F

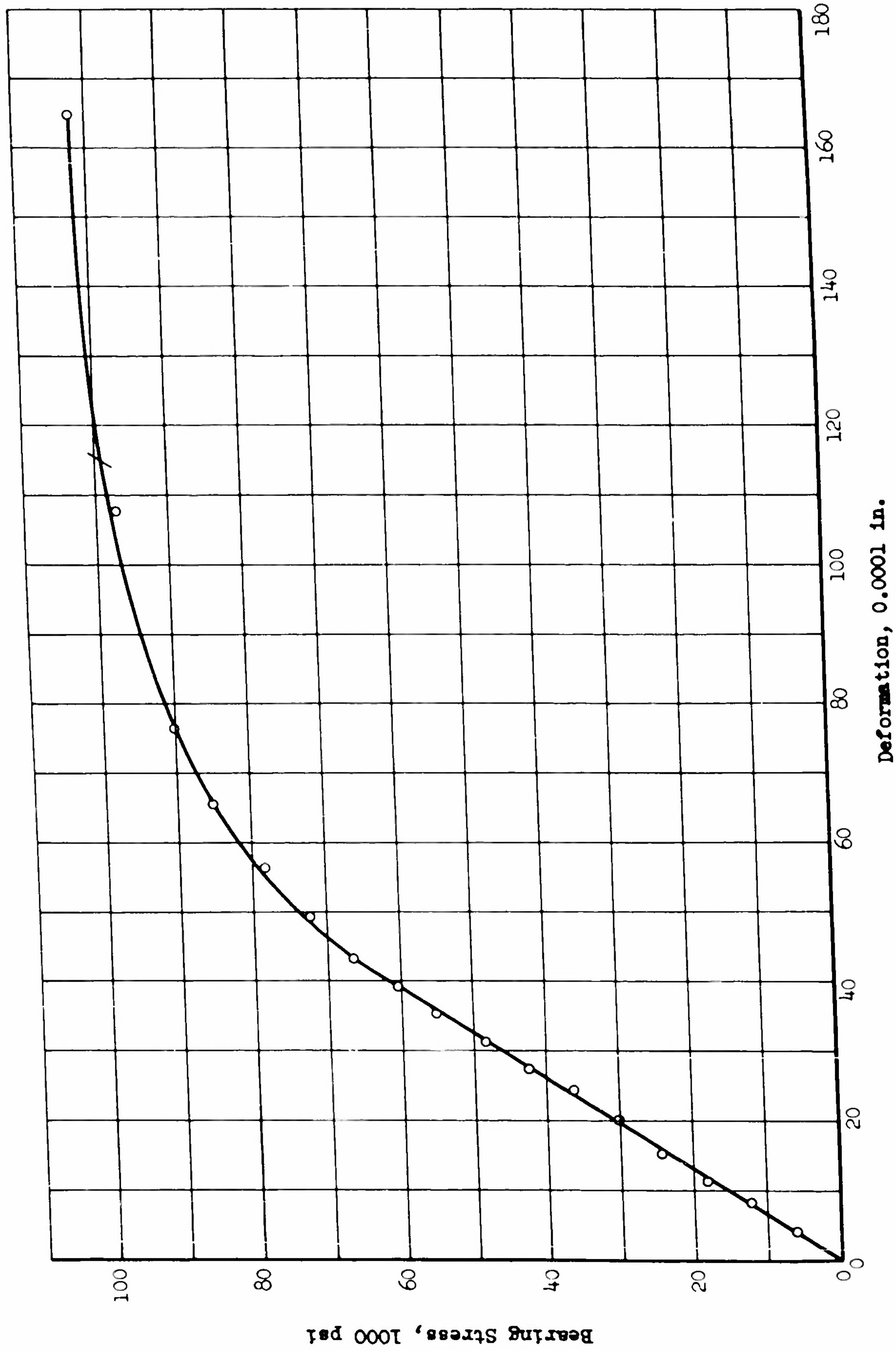

Fig. C-39 BEARING STRESS-DEFORMATION CURVE FOR 24S-T86 ALUMINUM ALLOY AT ROOM TEMPERATURE

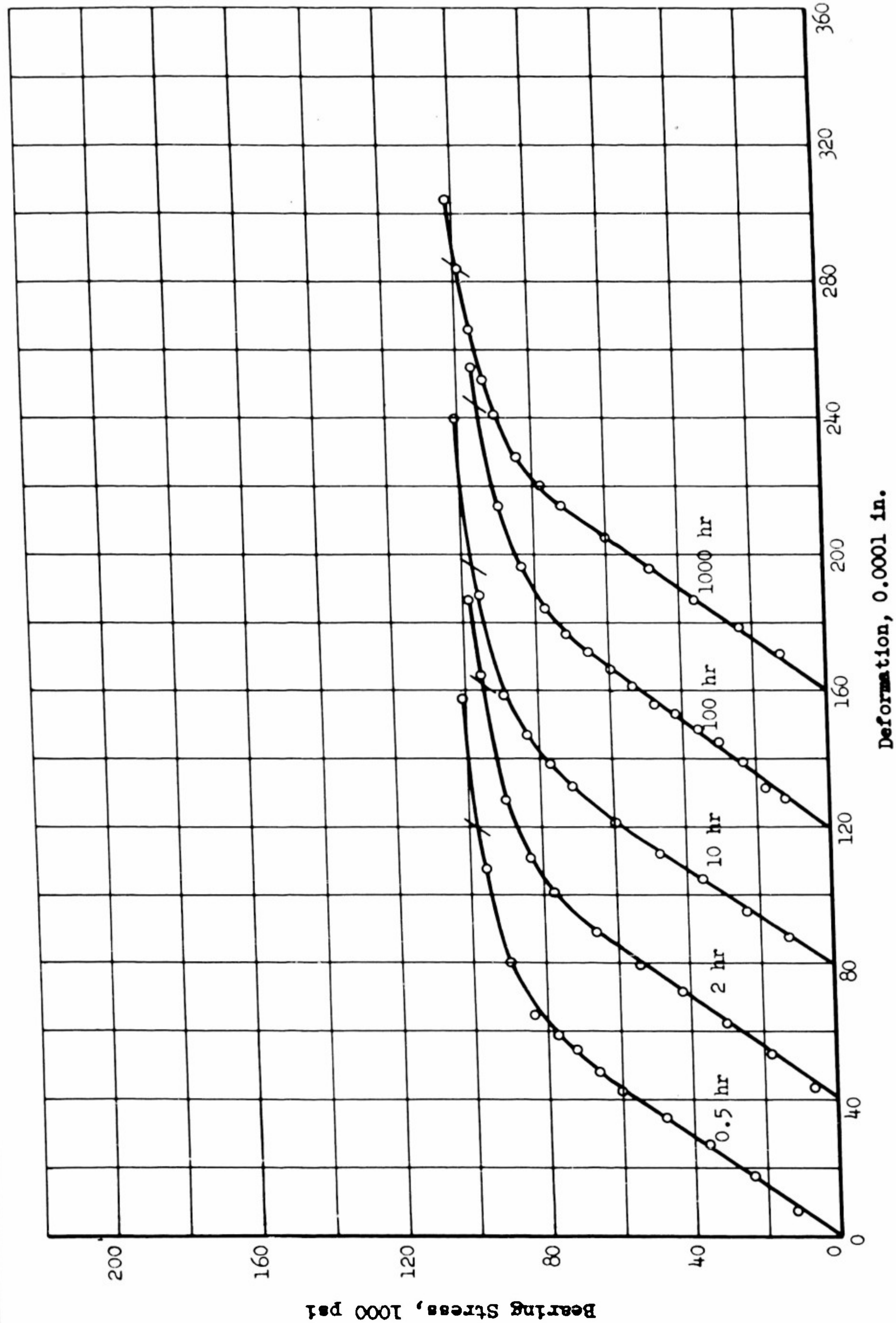

Fig. C-40 BEARING STRESS-DEFORMATION CURVES FOR 24S-T86 ALUMINUM ALLOY AT 200°F

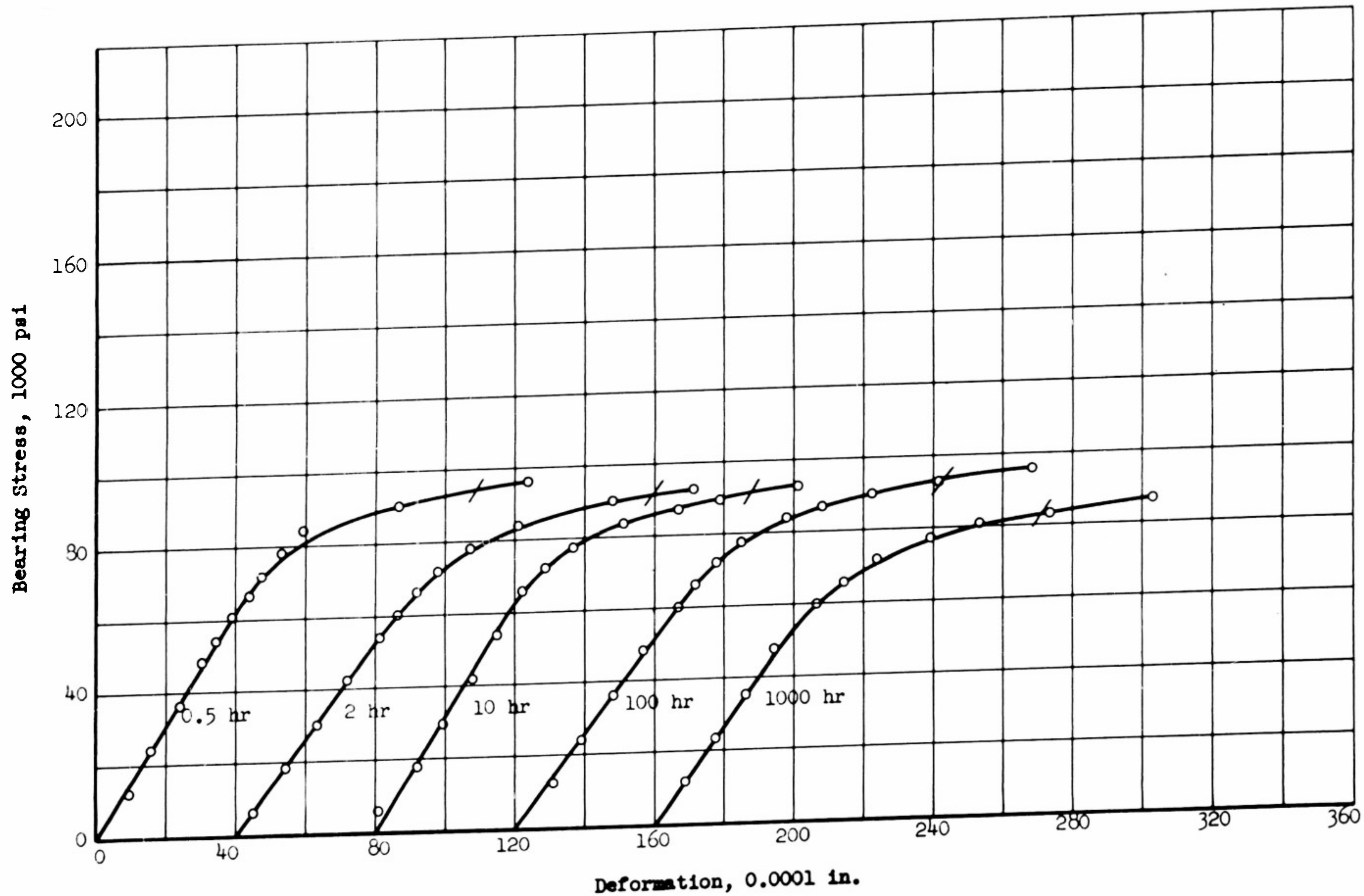

Fig. C-41 BEARING STRESS-DEFORMATION CURVES FOR 24S-T86 ALUMINUM ALLOY AT 300°F

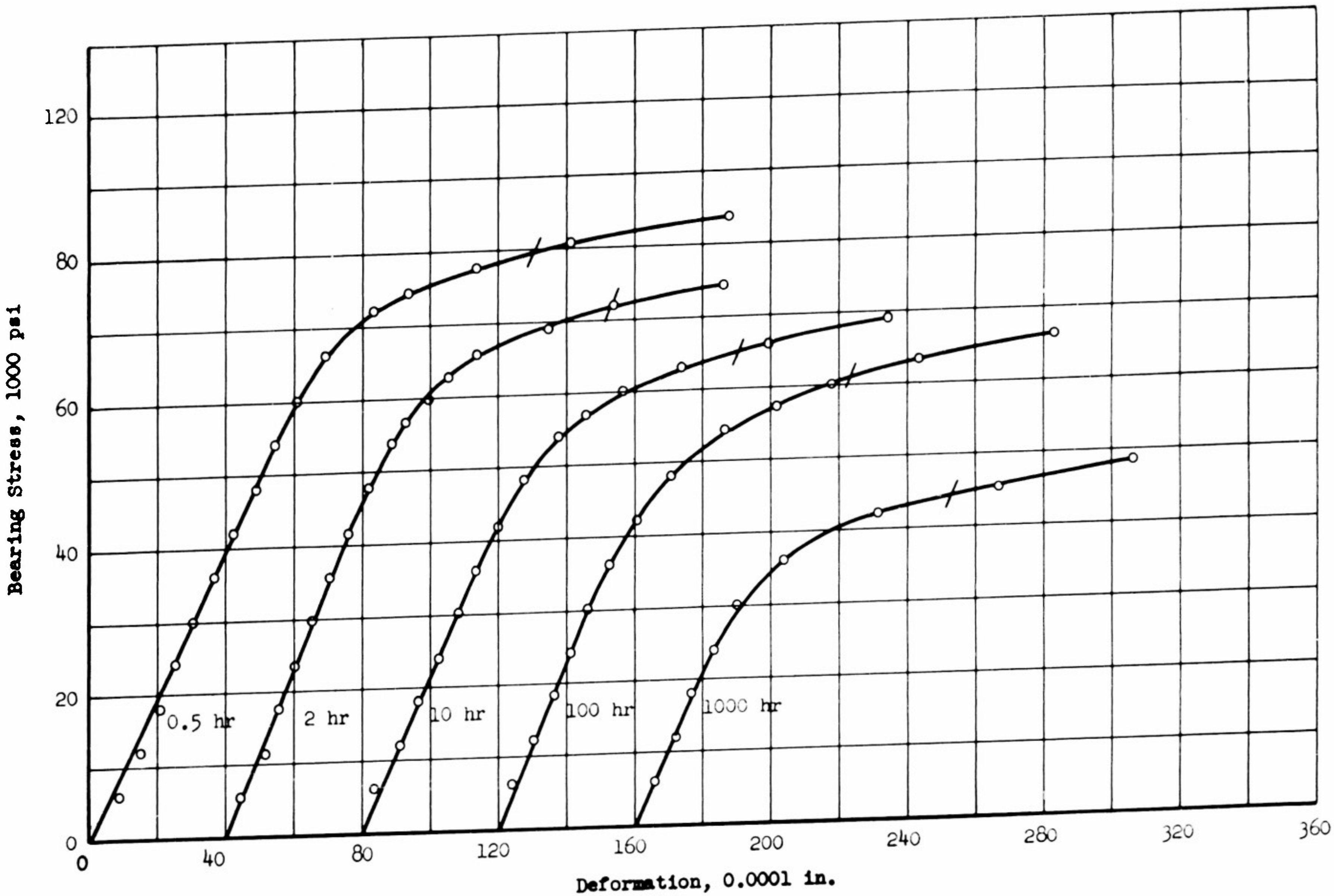

Fig. C-42 BEARING STRESS-DEFORMATION CURVES FOR 24S-T86 ALUMINUM ALLOY AT 400°F

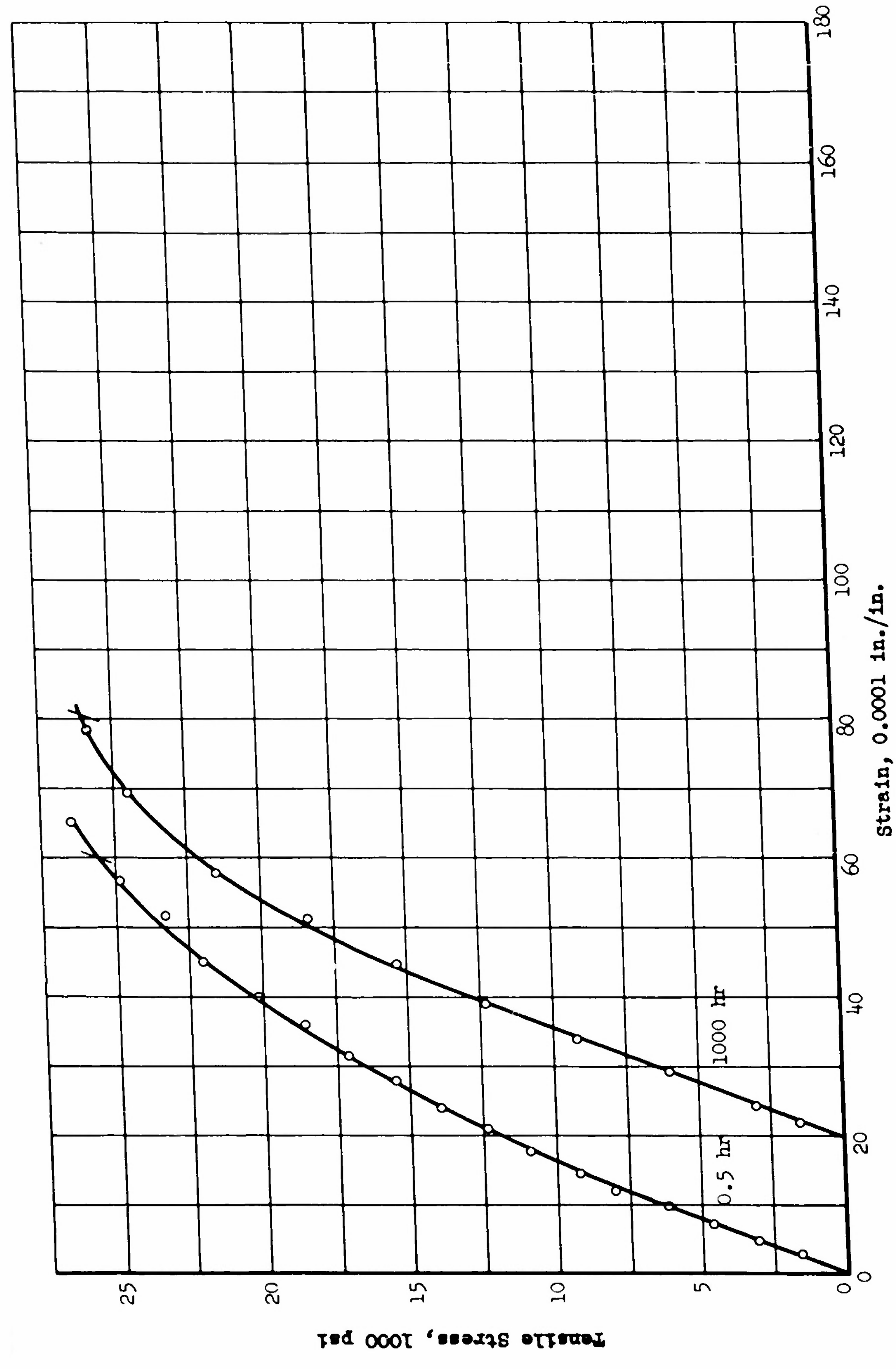

Fig. C-43 TENSILE STRESS-STRAIN CURVES FOR FS1-H24 MAGNESIUM ALLOY AT 200°F

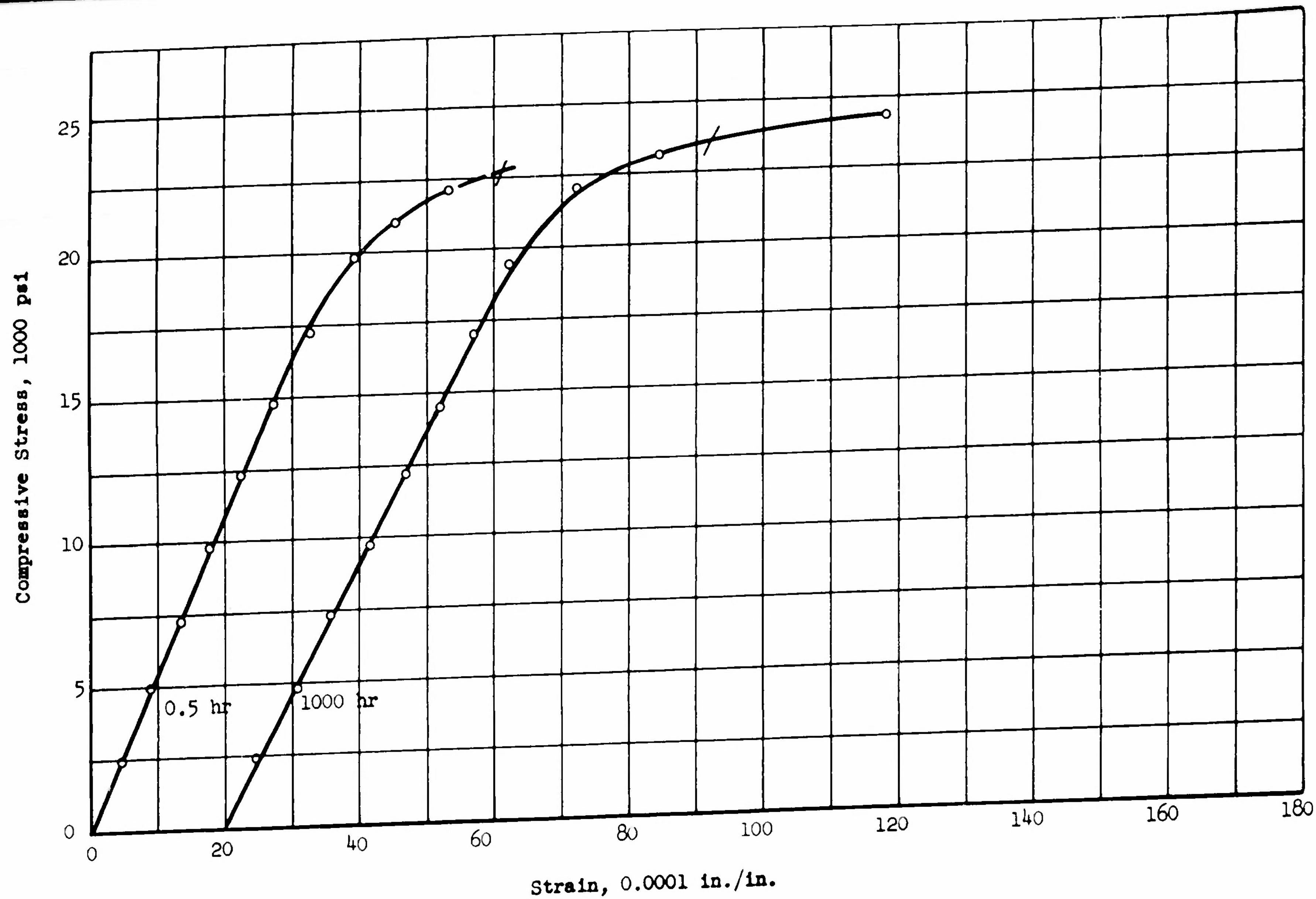

Fig. C-44 COMPRESSIVE STRESS-STRAIN CURVES FOR FS1-H24 MAGNESIUM ALLOY AT 200°F

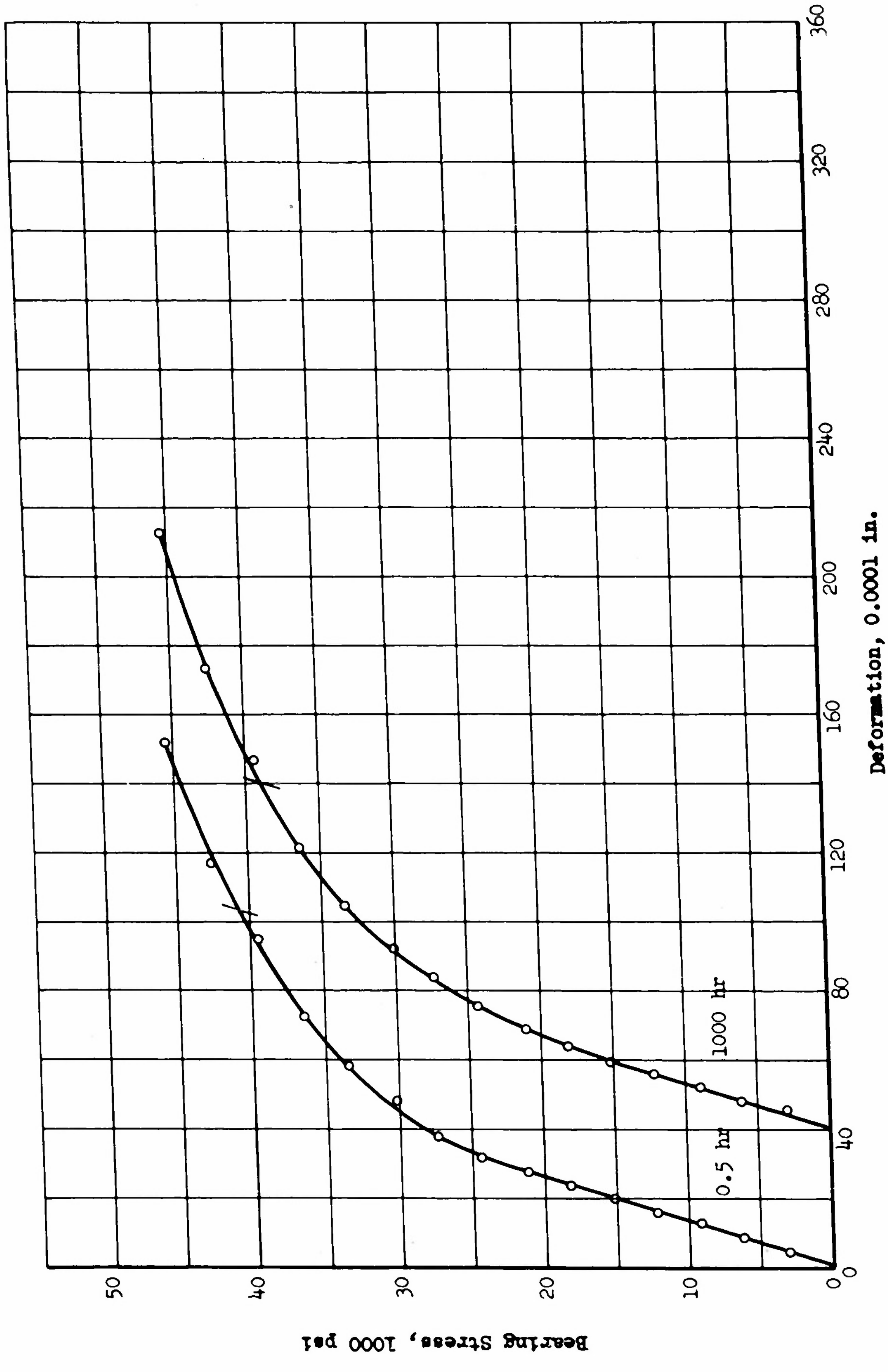

Fig. C-45 BEARING STRESS-DEFORMATION CURVES FOR FS1-H24 MAGNESIUM ALLOY AT 200°F

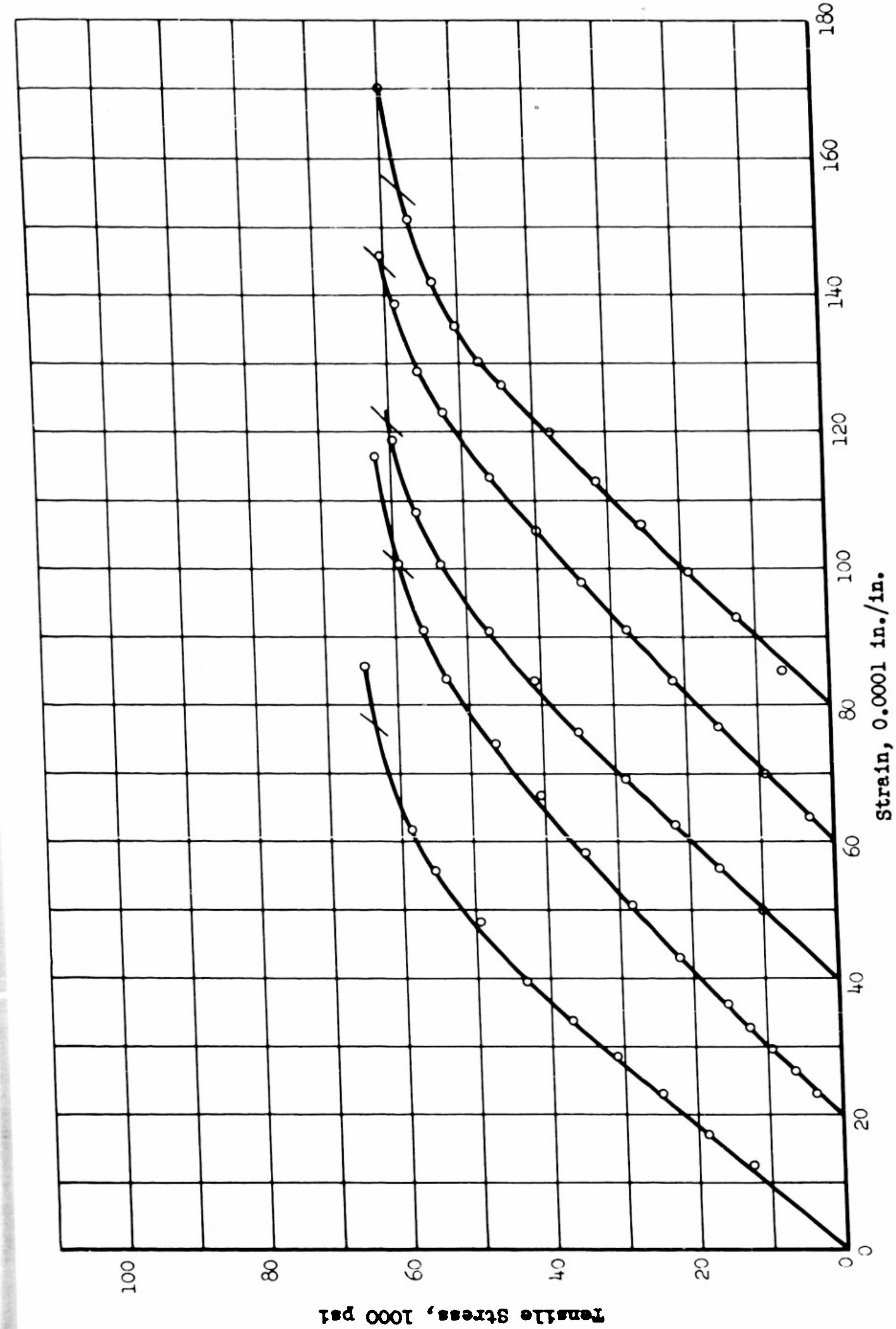

Fig. C-46 TENSILE STRESS-STRAIN CURVES FOR 75S-T6 ALUMINUM ALLOY AT 200°F

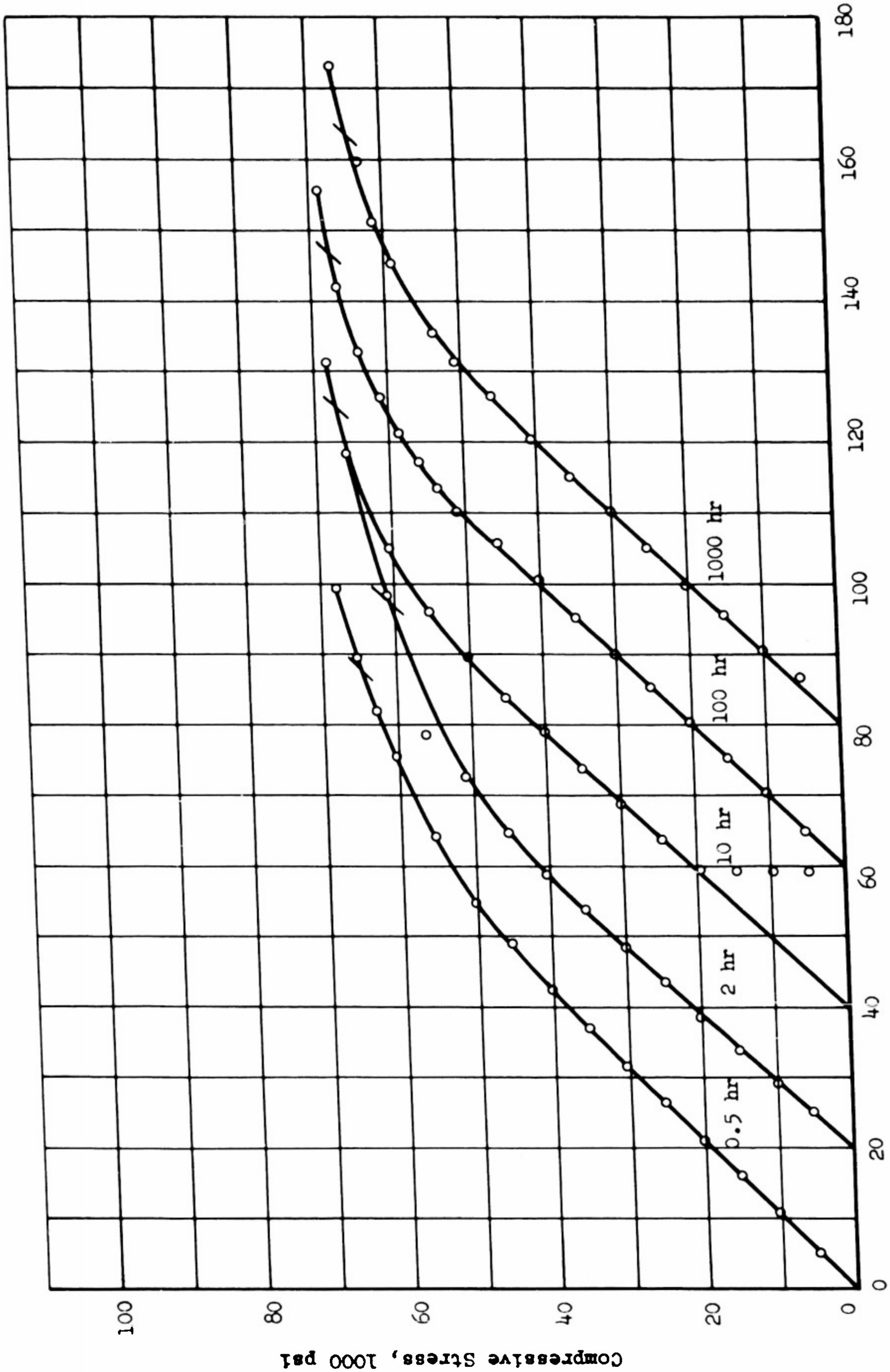

Fig. C-47 COMPRESSIVE STRESS-STRAIN CURVES FOR 75S-T6 ALUMINUM ALLOY AT 200°F

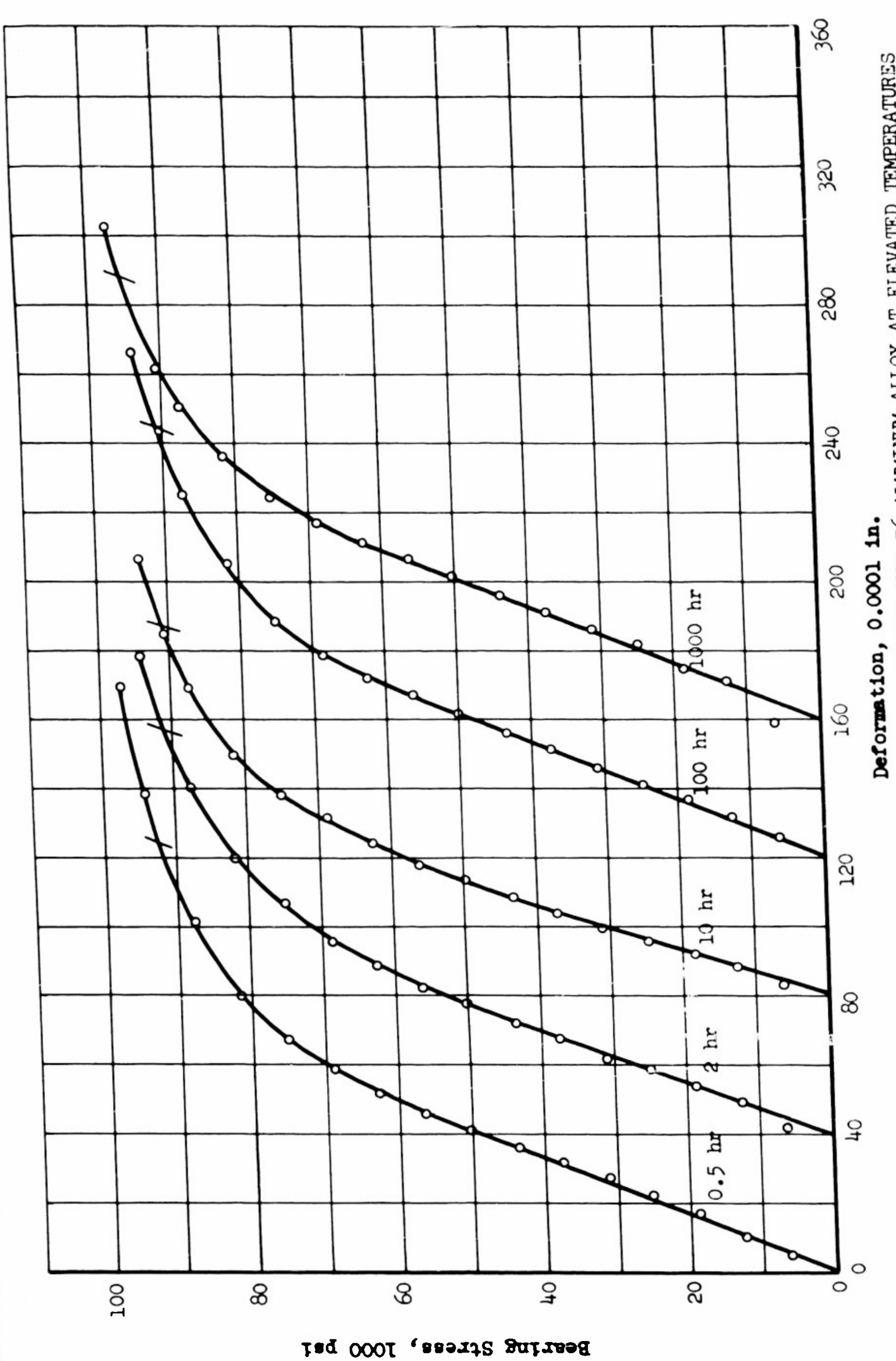

Fig. C-48 BEARING STRESS-DEFORMATION CURVES FOR 75S-T6 ALUMINUM ALLOY AT ELEVATED TEMPERATURES

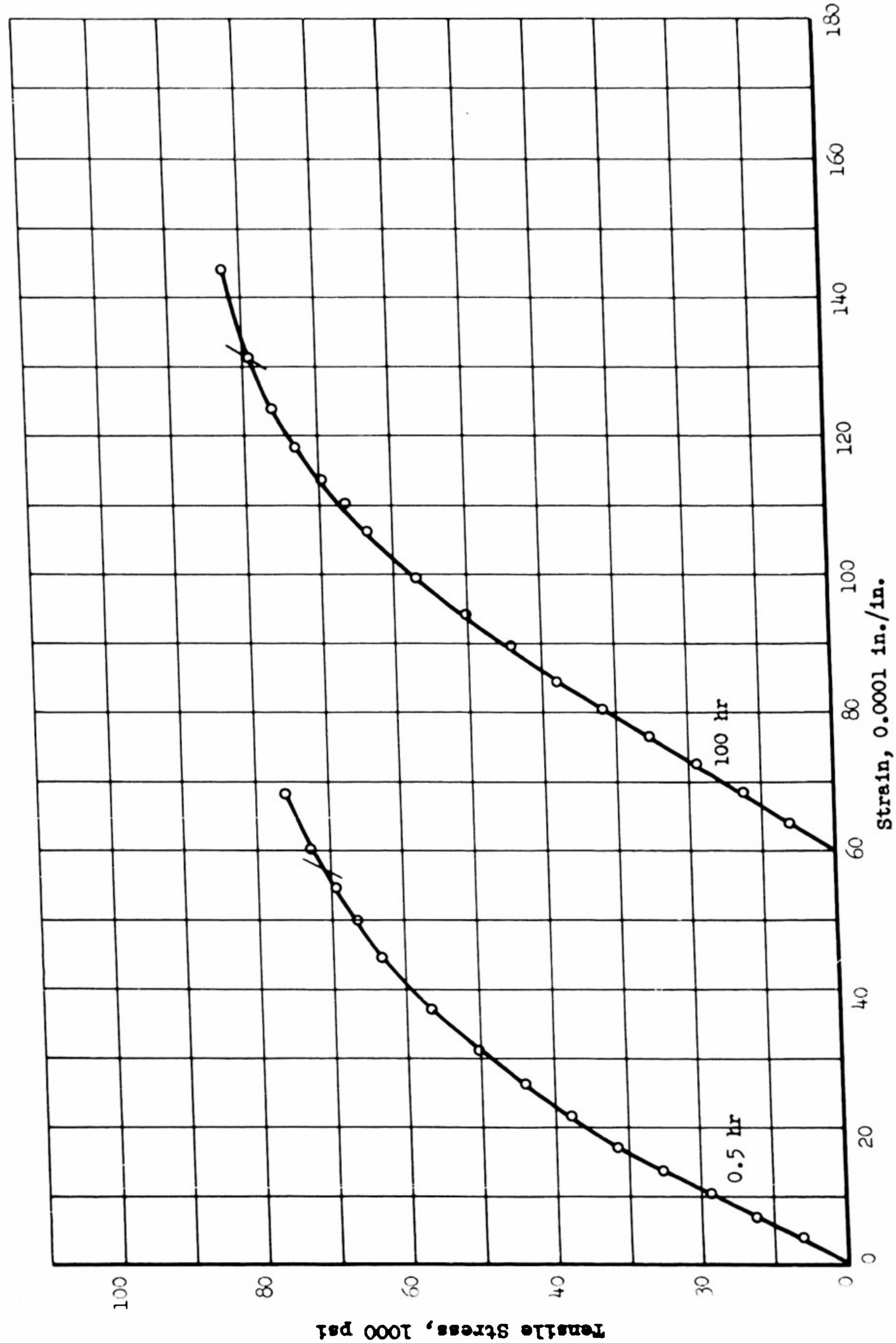

Fig. C-49 TENSILE STRESS-STRAIN CURVES FOR COLD ROLLED TITANIUM AT 200°F

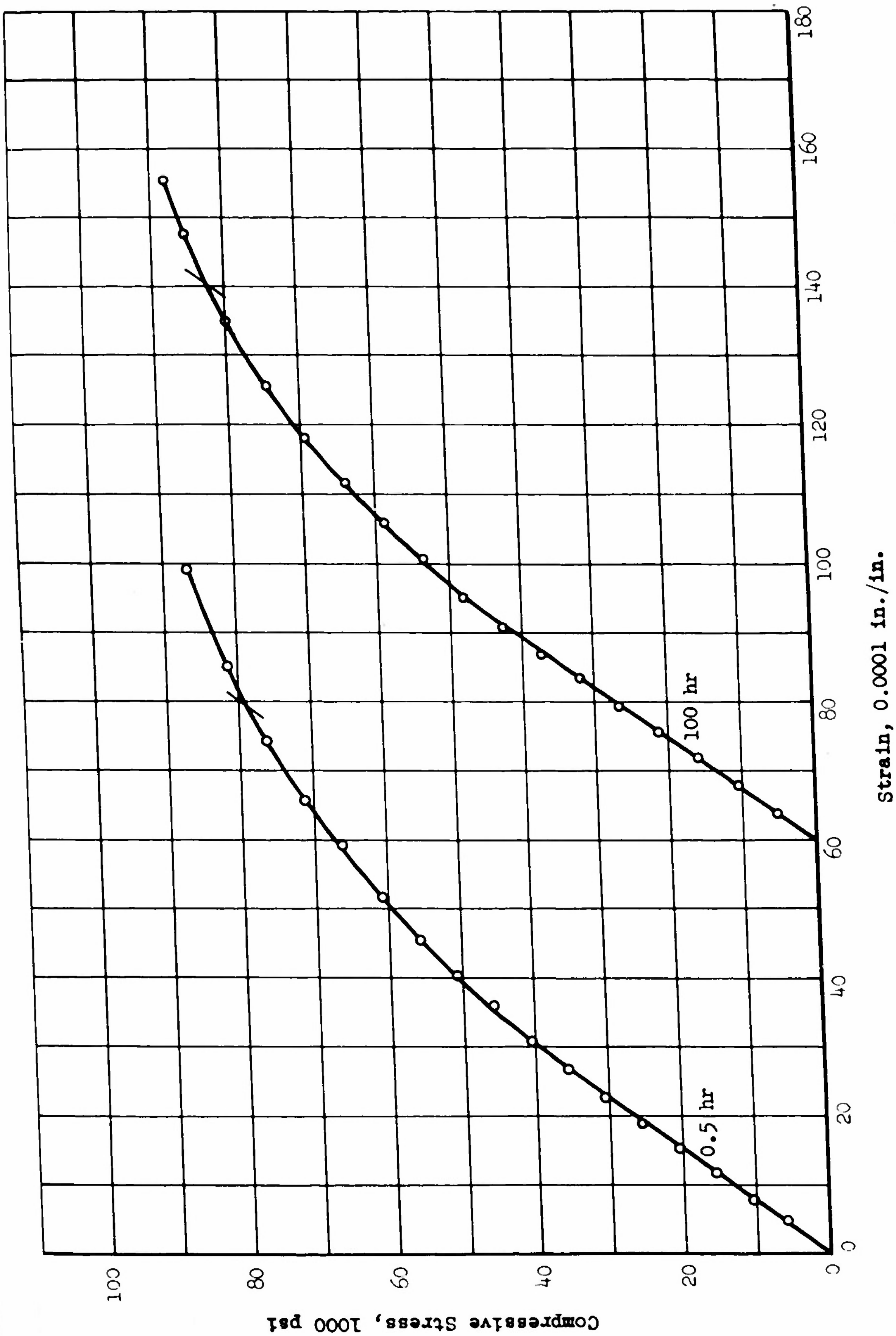

Fig. C-50 COMPRESSIVE STRESS-STRAIN CURVES FOR COLD ROLLED TITANIUM AT 200°F

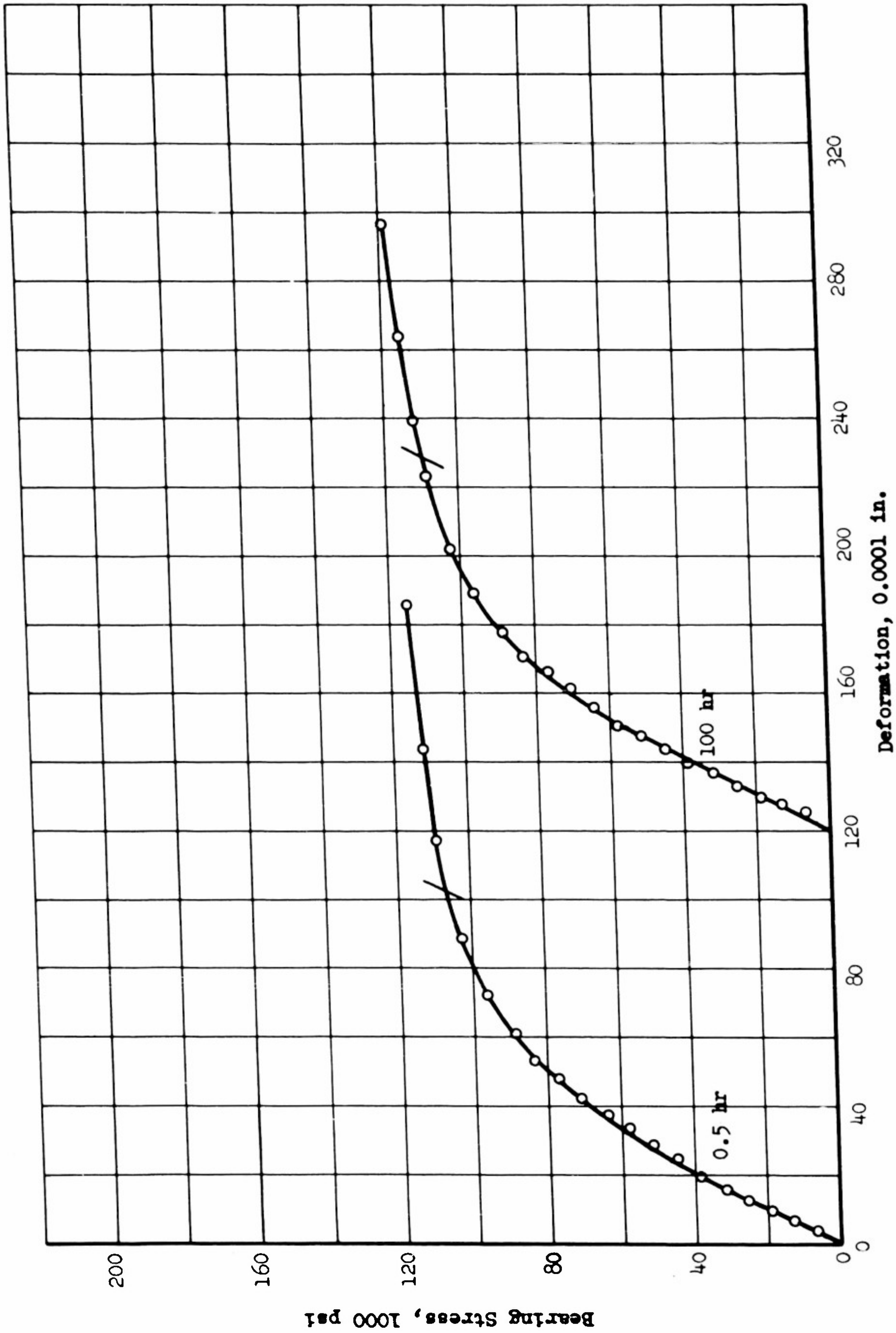

Fig. C-51 BEARING STRESS-DEFORMATION CURVES FOR COLD ROLLED TITANIUM AT 200°F

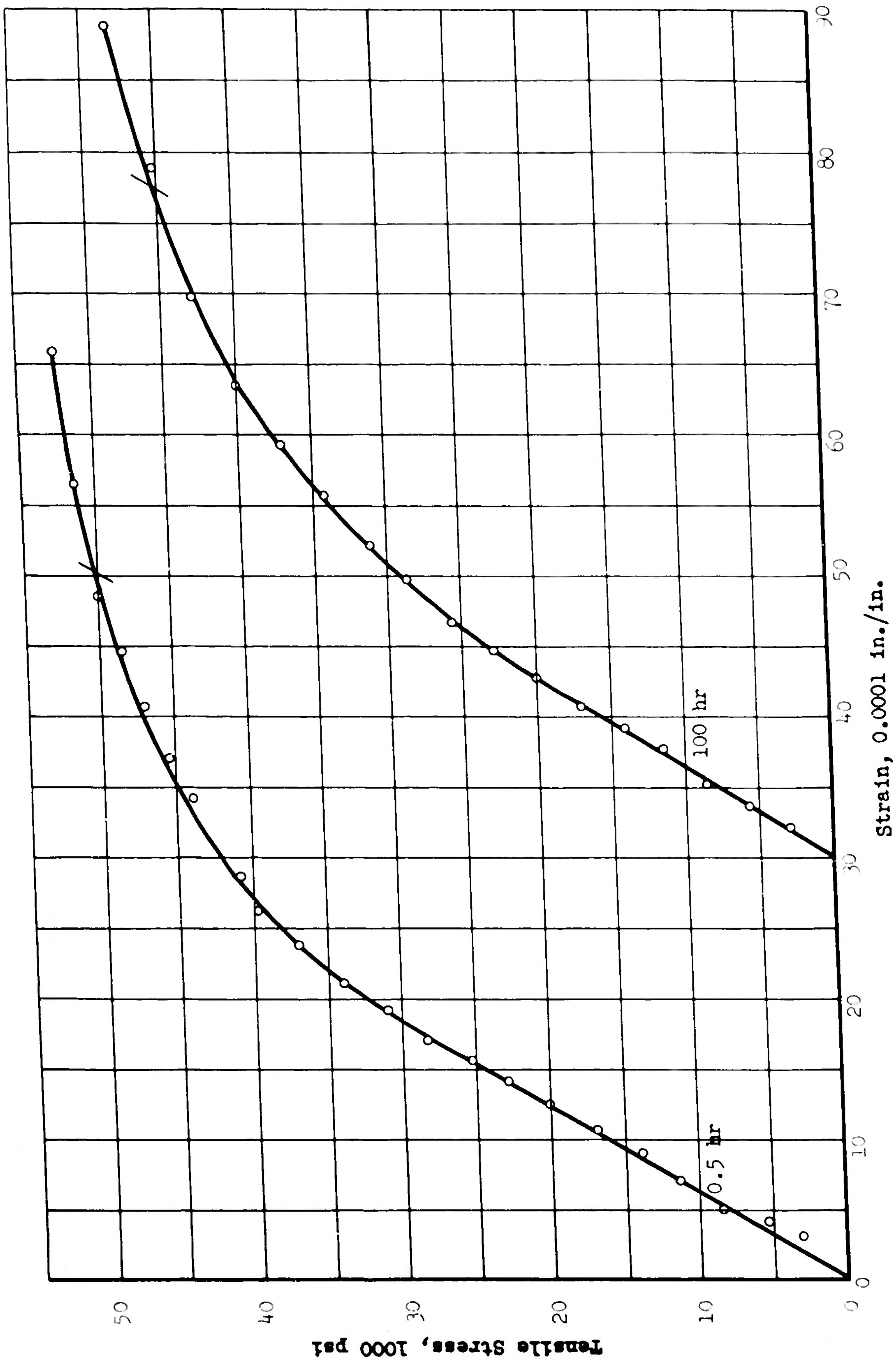

Fig. C-52 TENSILE STRESS-STRAIN CURVES FOR ANNEALED TITANIUM AT 200°F

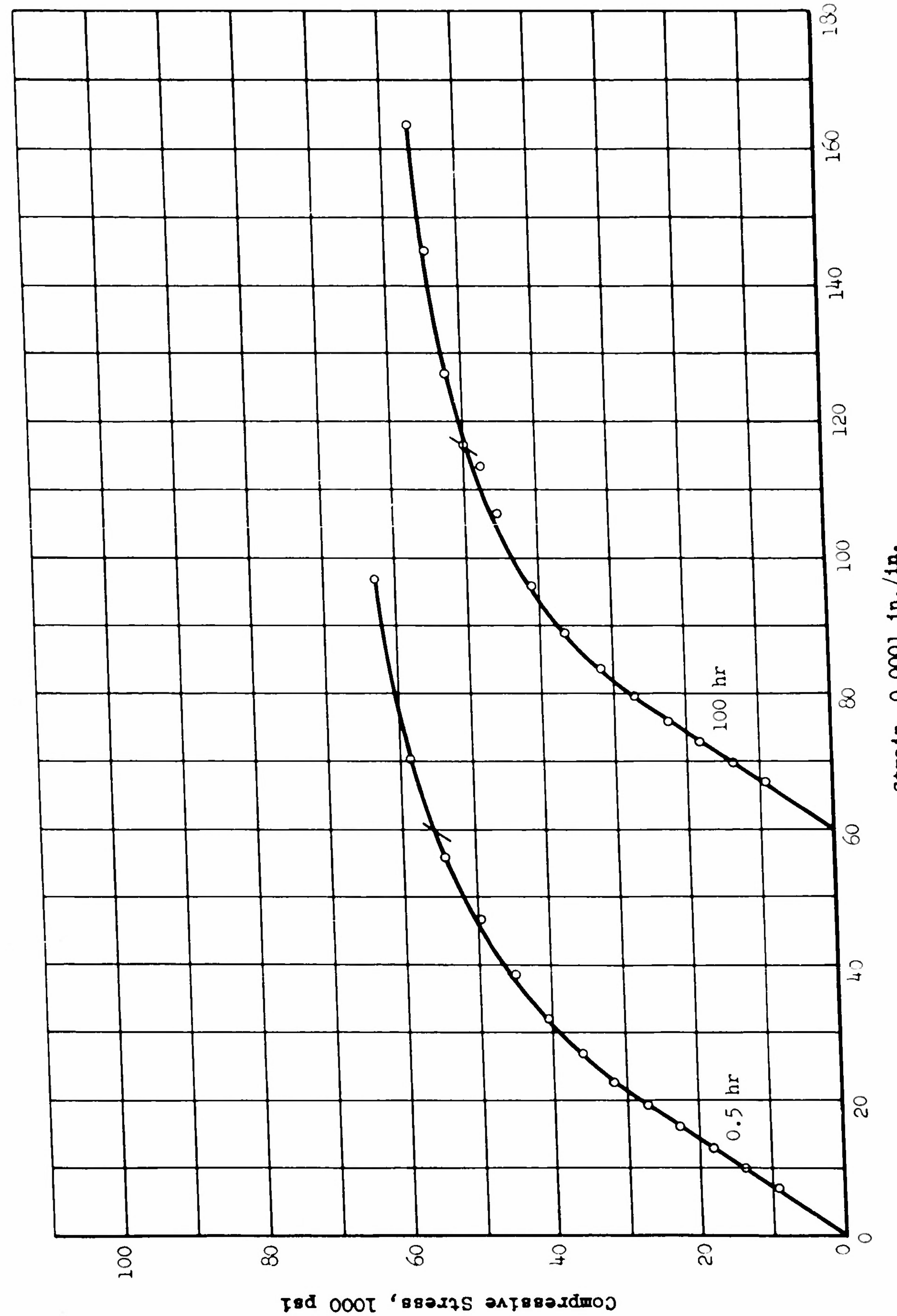

Fig. C-53 COMPRESSIVE STRESS-STRAIN CURVES FOR ANNEALED TITANIUM AT 200°F

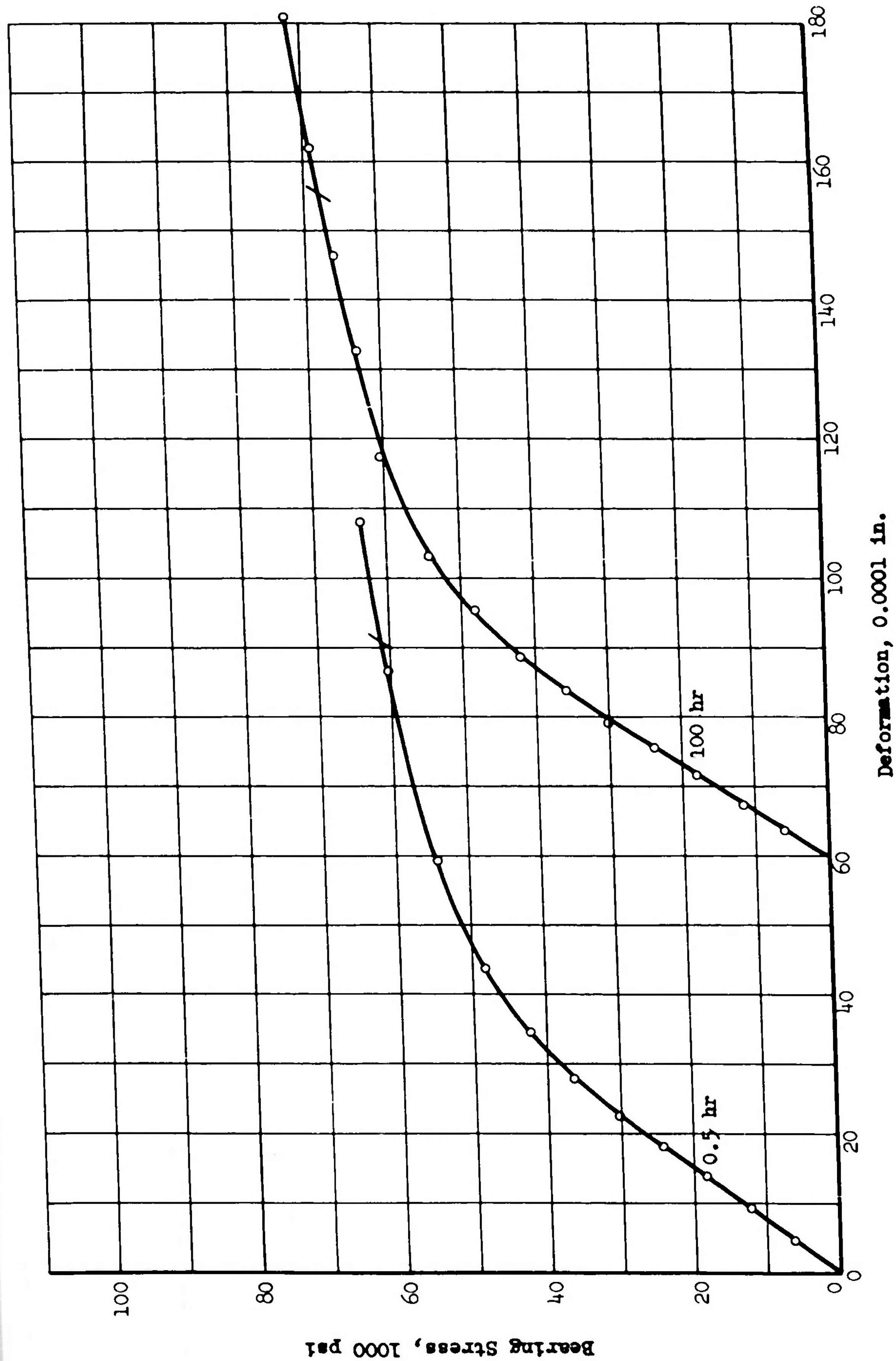

Fig. C-54 BEARING STRESS-DEFORMATION CURVES FOR ANNEALED TITANIUM AT 200°F

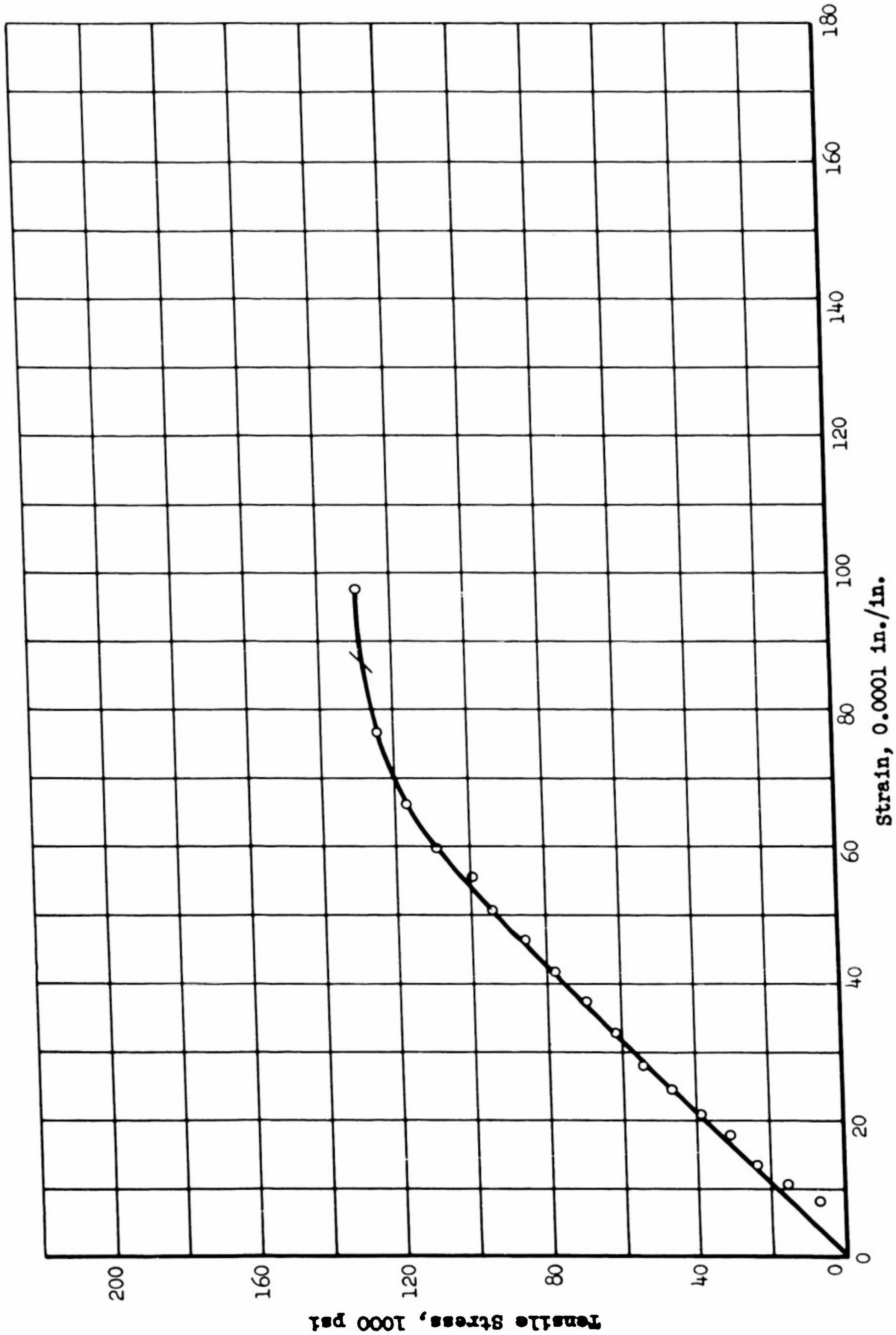

Fig. C-55 TENSILE STRESS-STRAIN CURVE FOR RC-130-A TITANIUM ALLOY AT ROOM TEMPERATURE

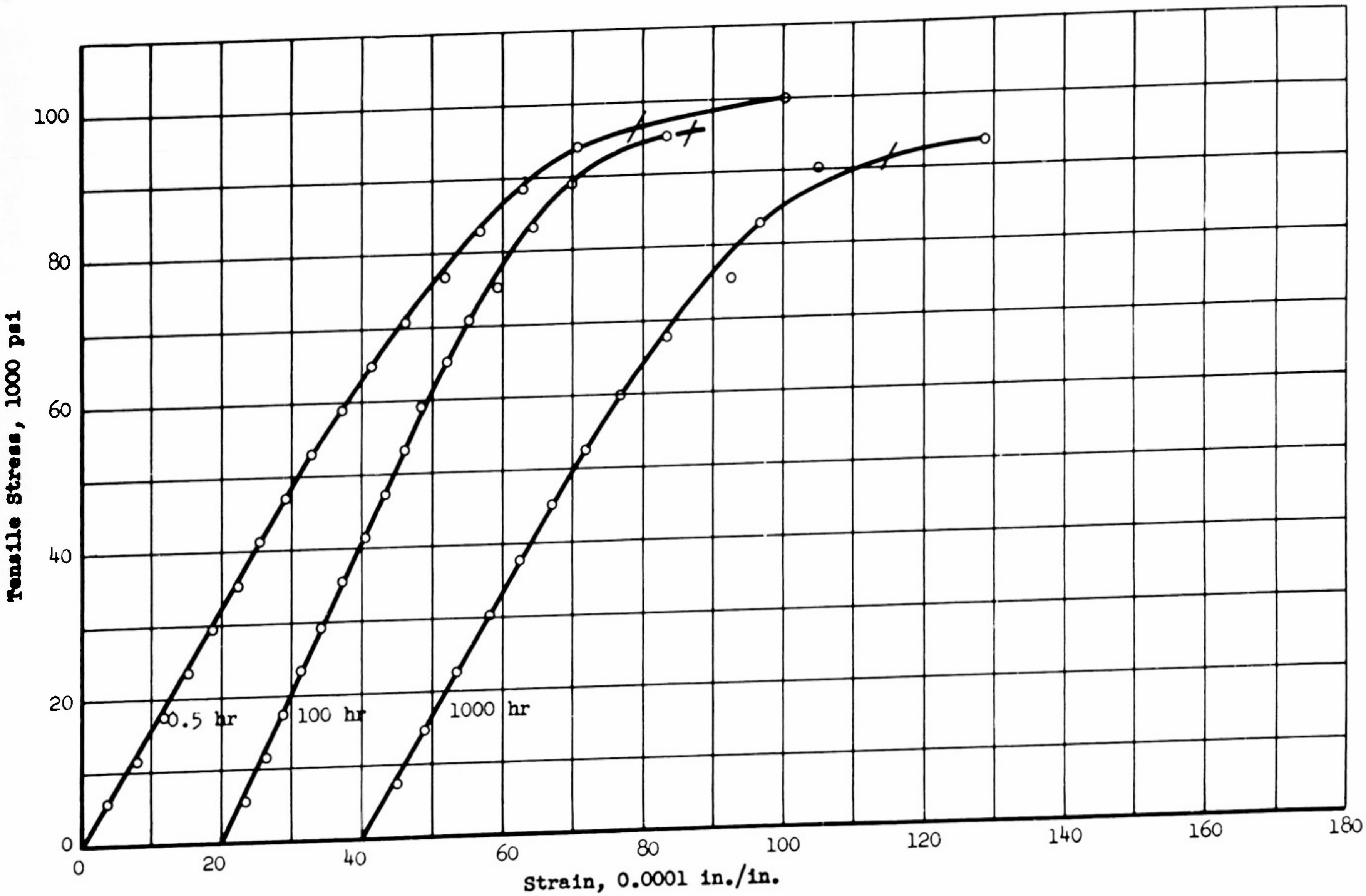

Fig. C-56 TENSILE STRESS-STRAIN CURVES FOR RC-130-A TITANIUM ALLOY AT 300°F

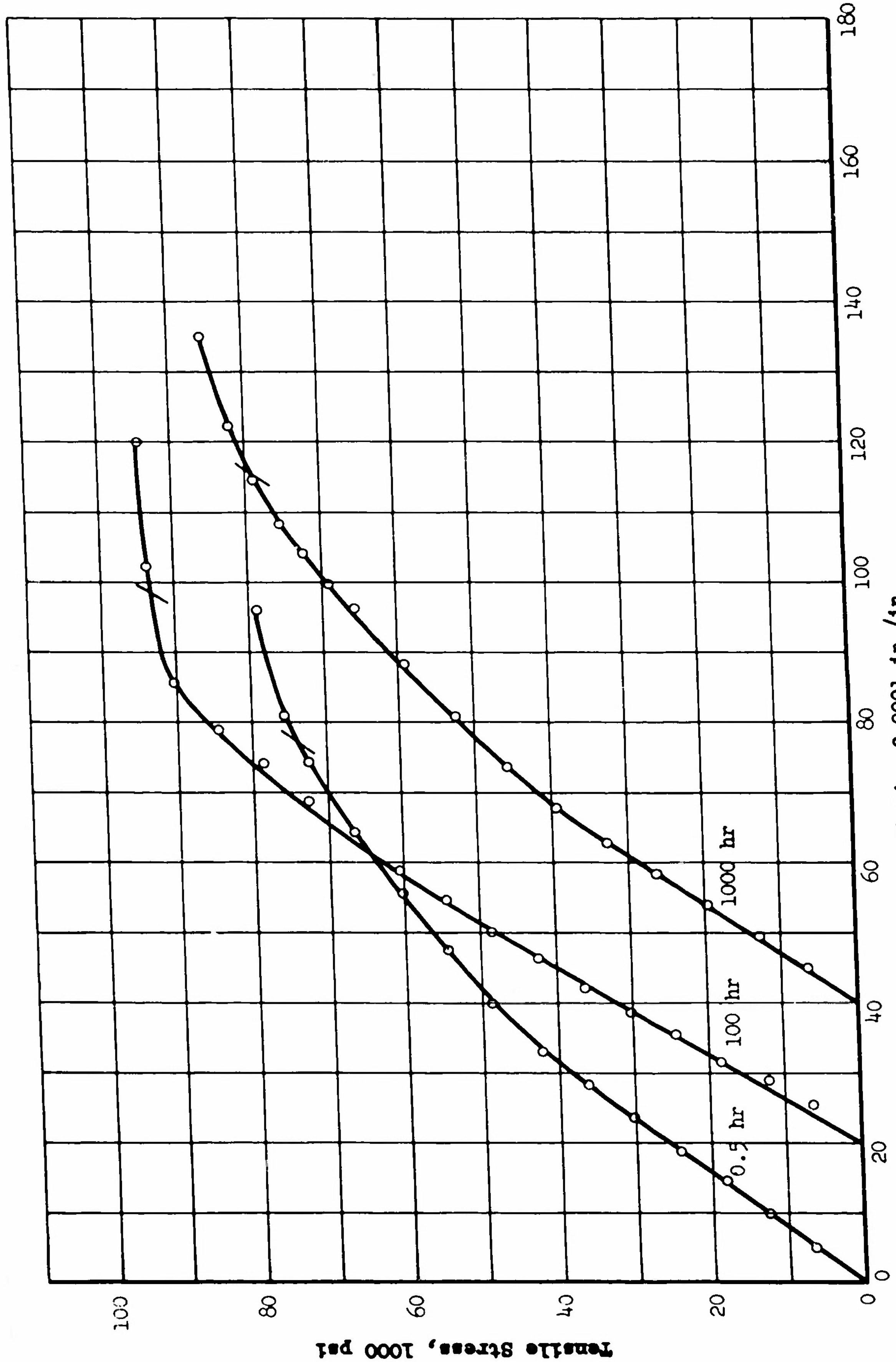

Fig. C-57 TENSILE STRESS-STRAIN CURVES FOR RC-130-A TITANIUM ALLOY AT 500°F

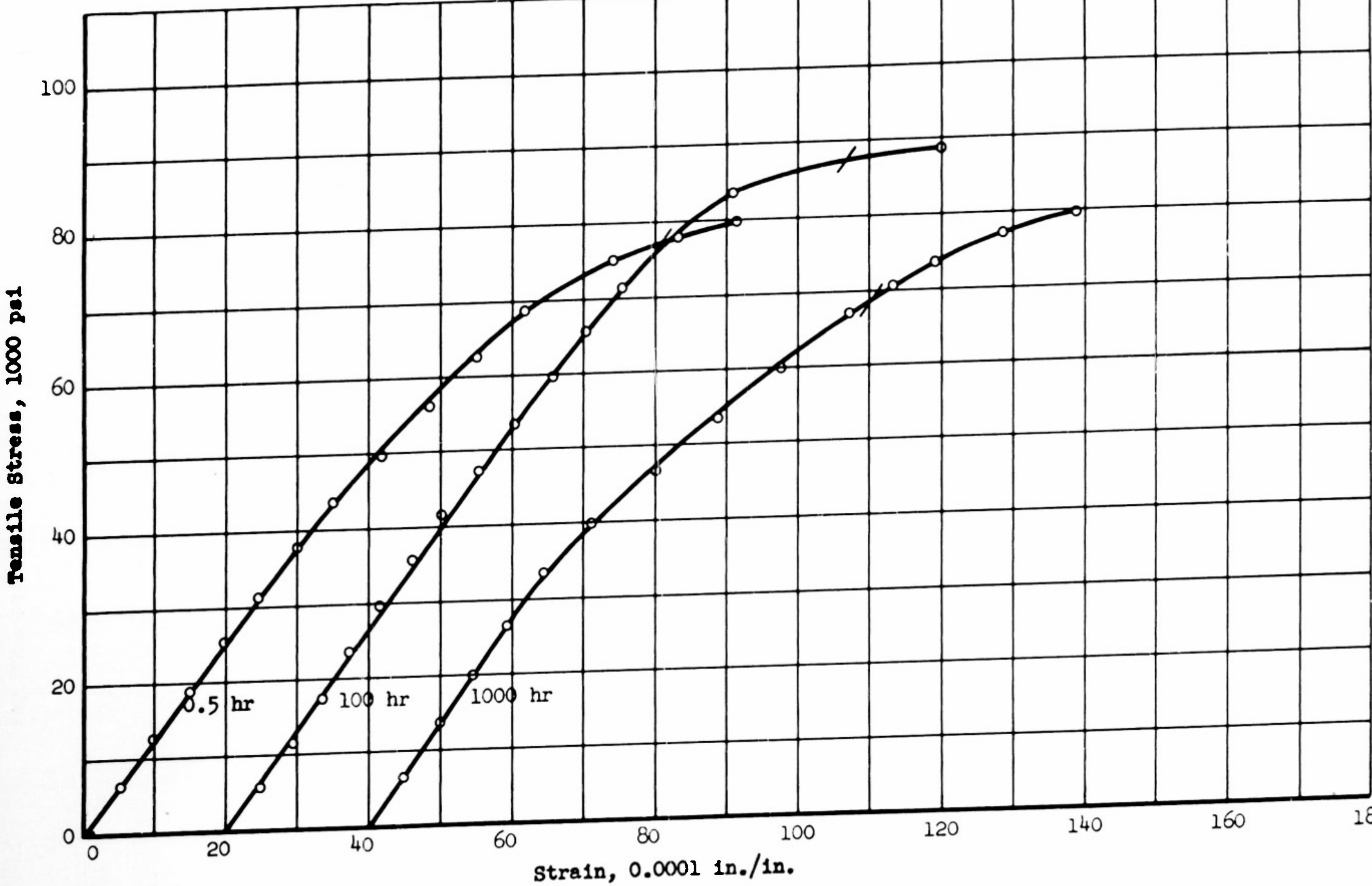

Fig. C-58 TENSILE STRESS-STRAIN CURVES FOR RC-130-A TITANIUM ALLOY AT 600°F

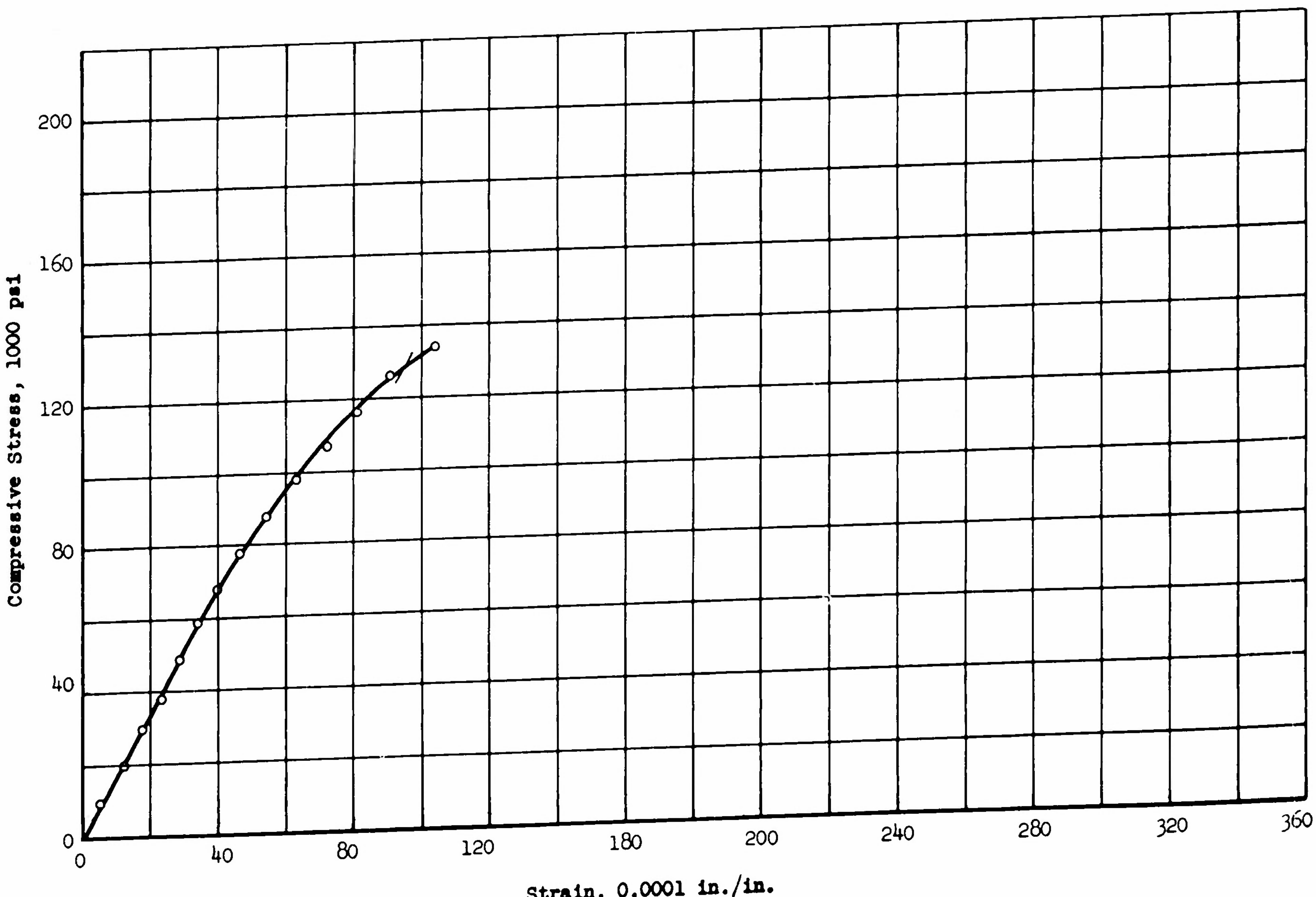

Fig. C-59 COMPRESSIVE STRESS-STRAIN CURVE FOR RC-130-A TITANIUM ALLOY AT ROOM TEMPERATURE

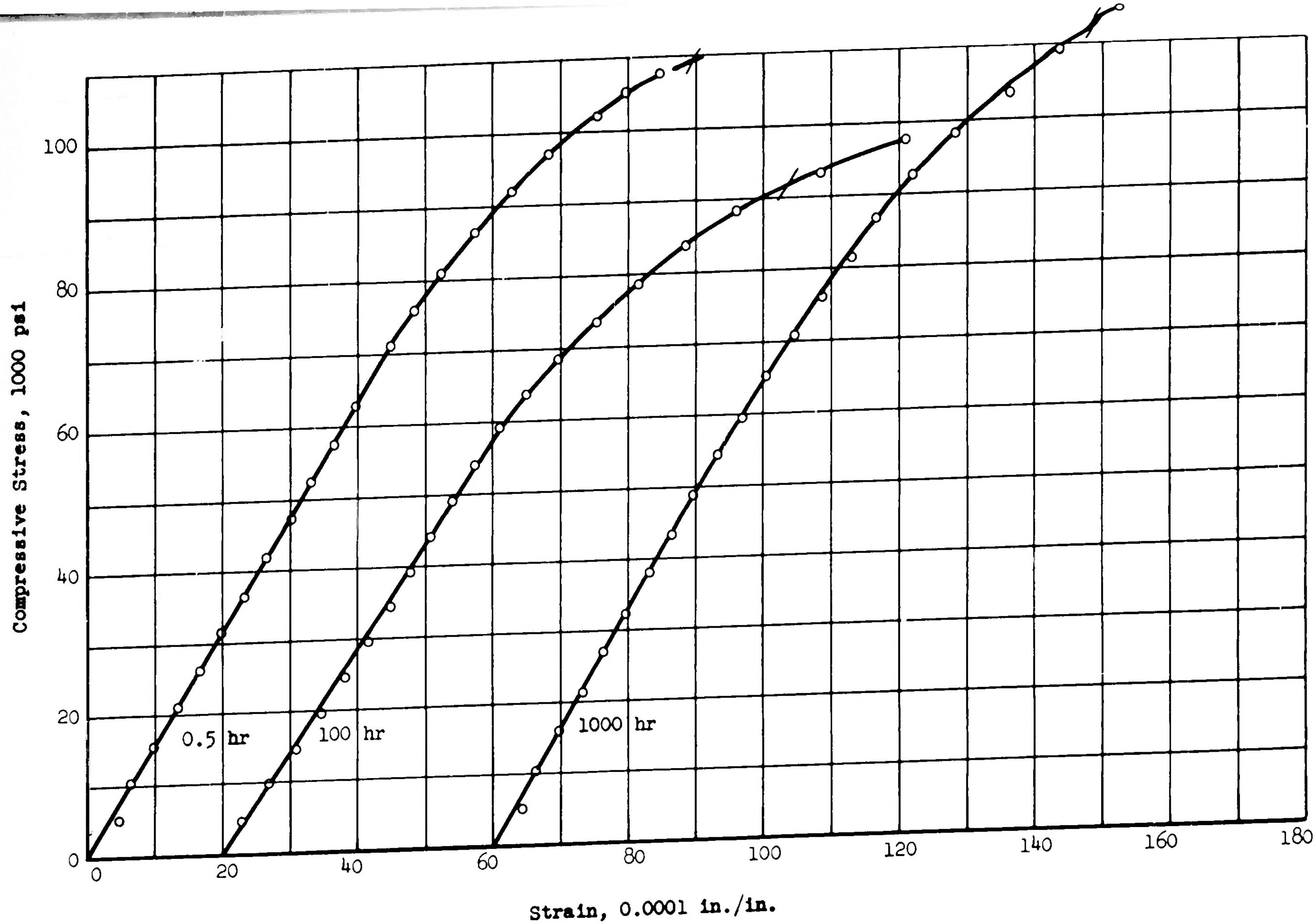

Fig. C-60 COMPRESSIVE STRESS-STRAIN CURVES FOR RC-130-A TITANIUM ALLOY AT 300°F

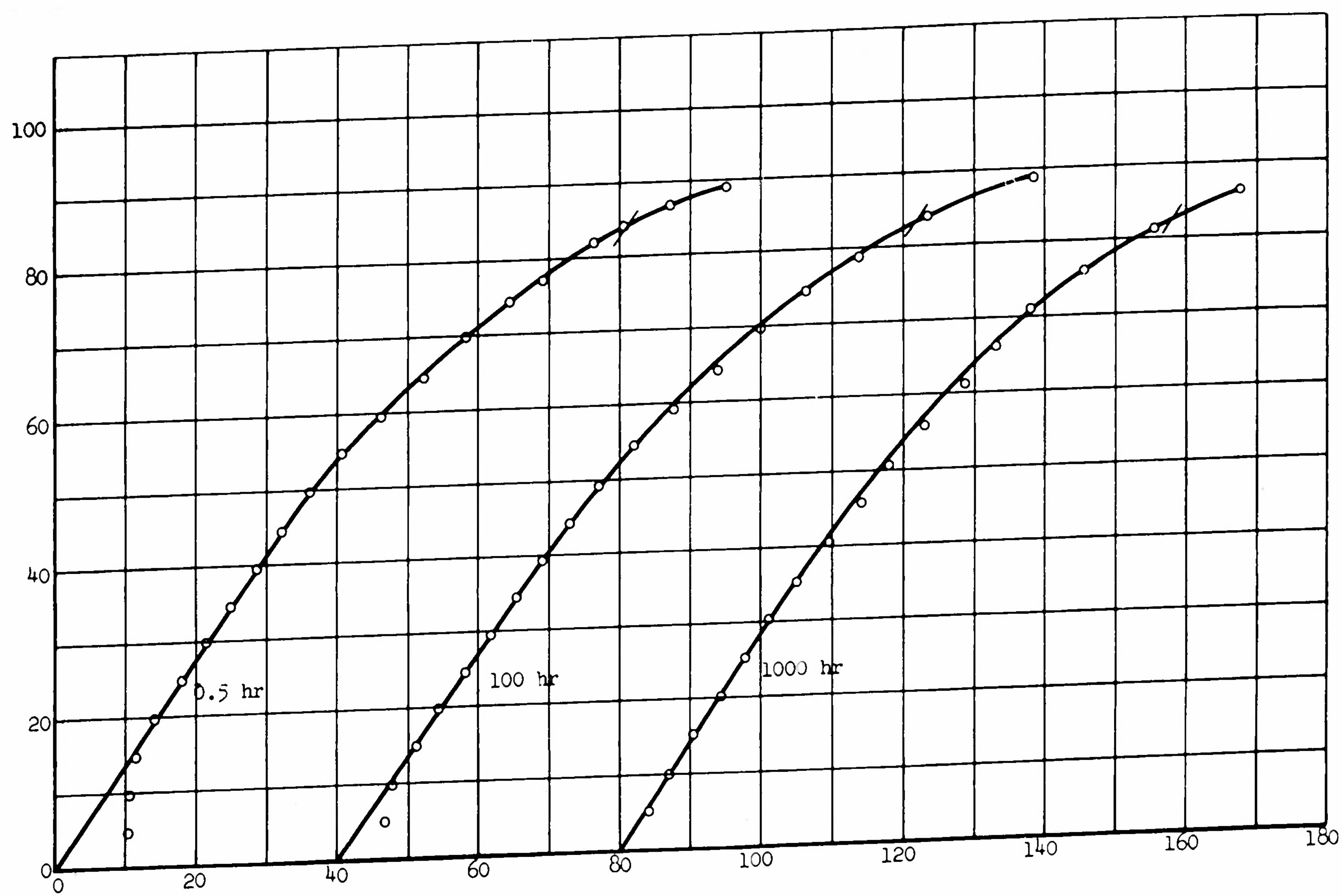

Fig. C-61 COMPRESSIVE STRESS-STRAIN CURVES FOR RC-130-A TITANIUM ALLOY AT 500°F

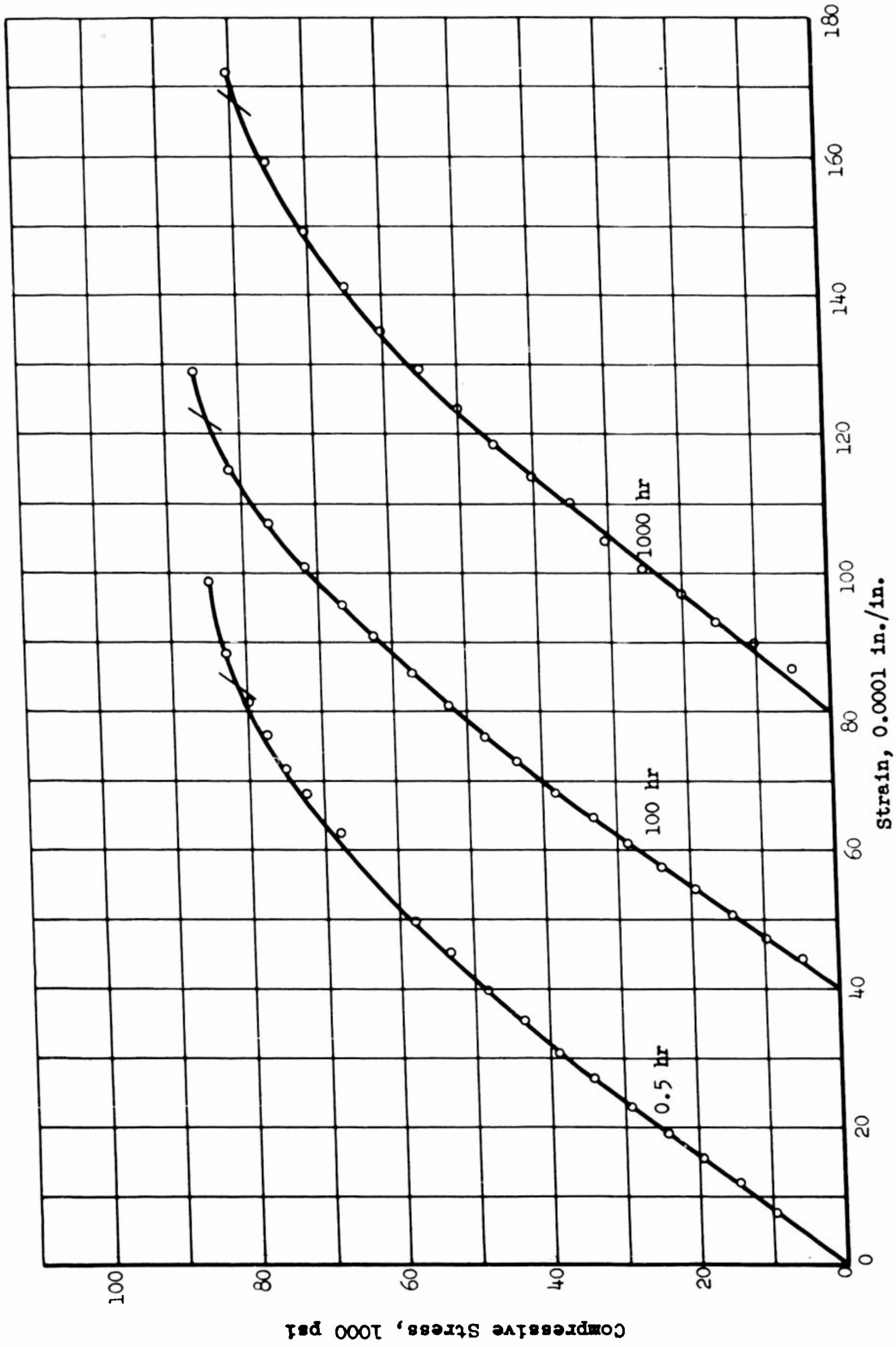

Fig. C-62 COMPRESSIVE STRESS-STRAIN CURVES FOR RC-130-A TITANIUM ALLOY AT 600°F

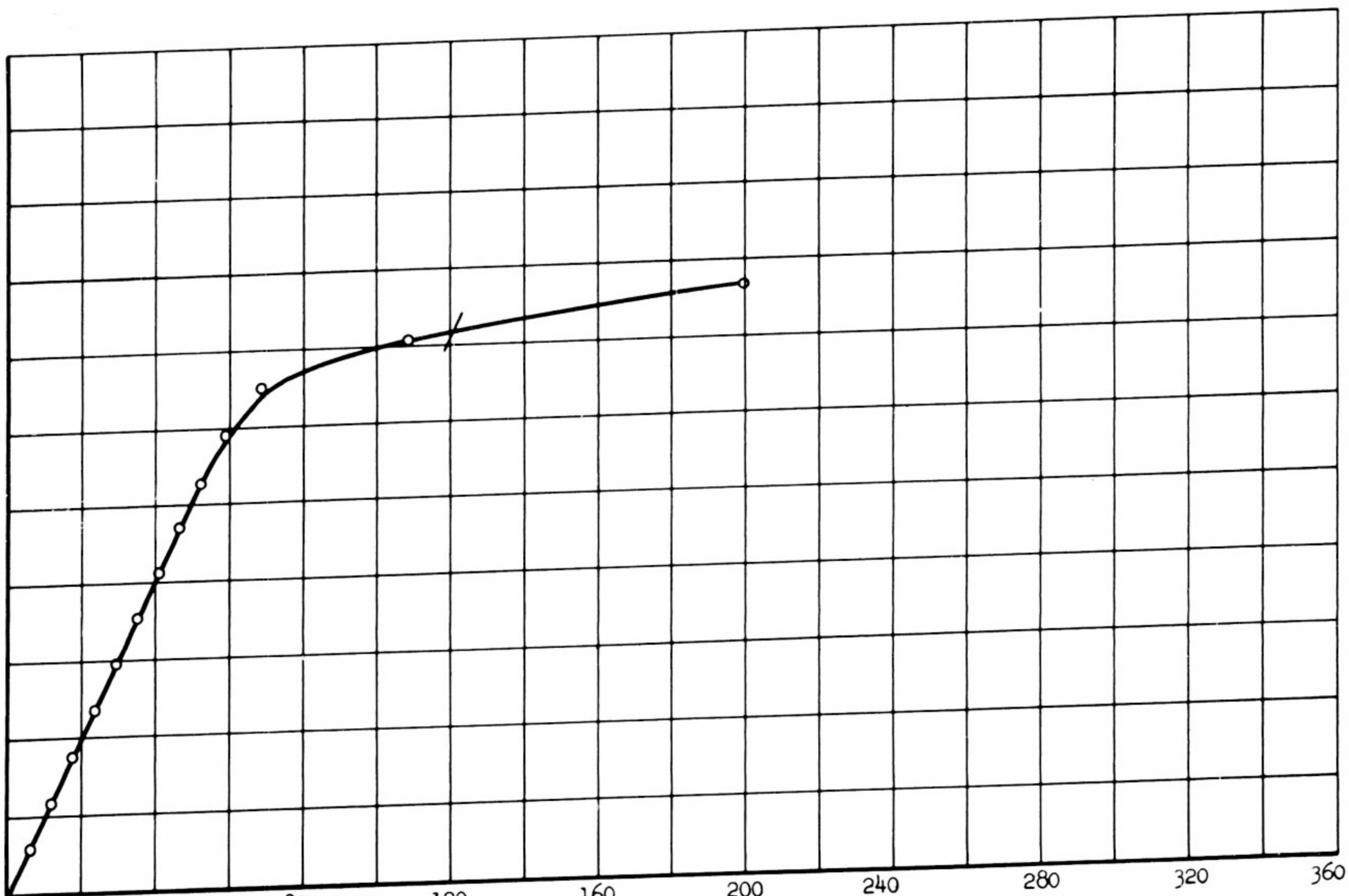

Fig. C-63 BEARING STRESS-DEFORMATION CURVE FOR RC-130-A TITANIUM ALLOY AT ROOM TEMPERATURE

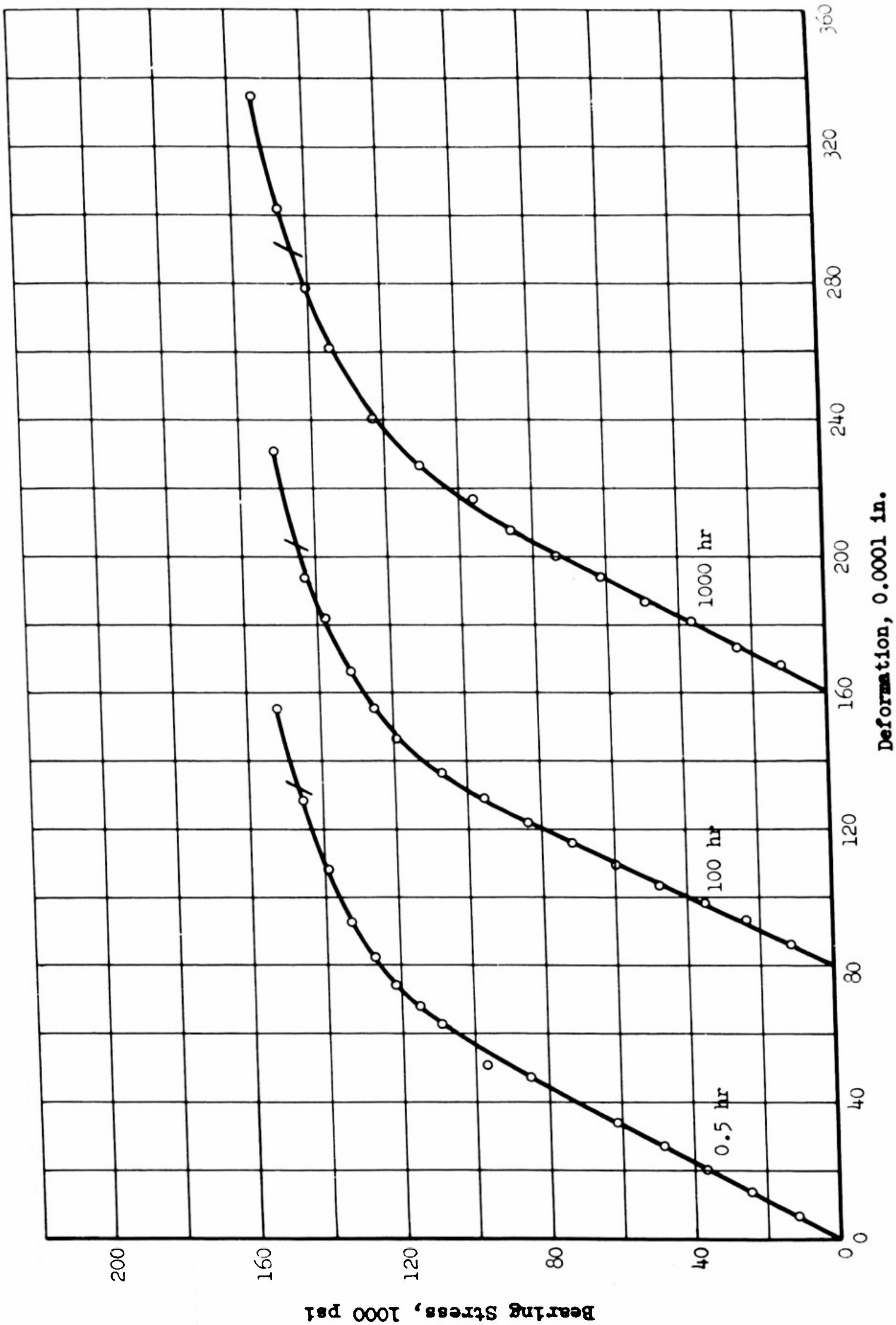

Fig. C-64 BEARING STRESS-DEFORMATION CURVES FOR RC-130-A TITANIUM ALLOY AT 300°F

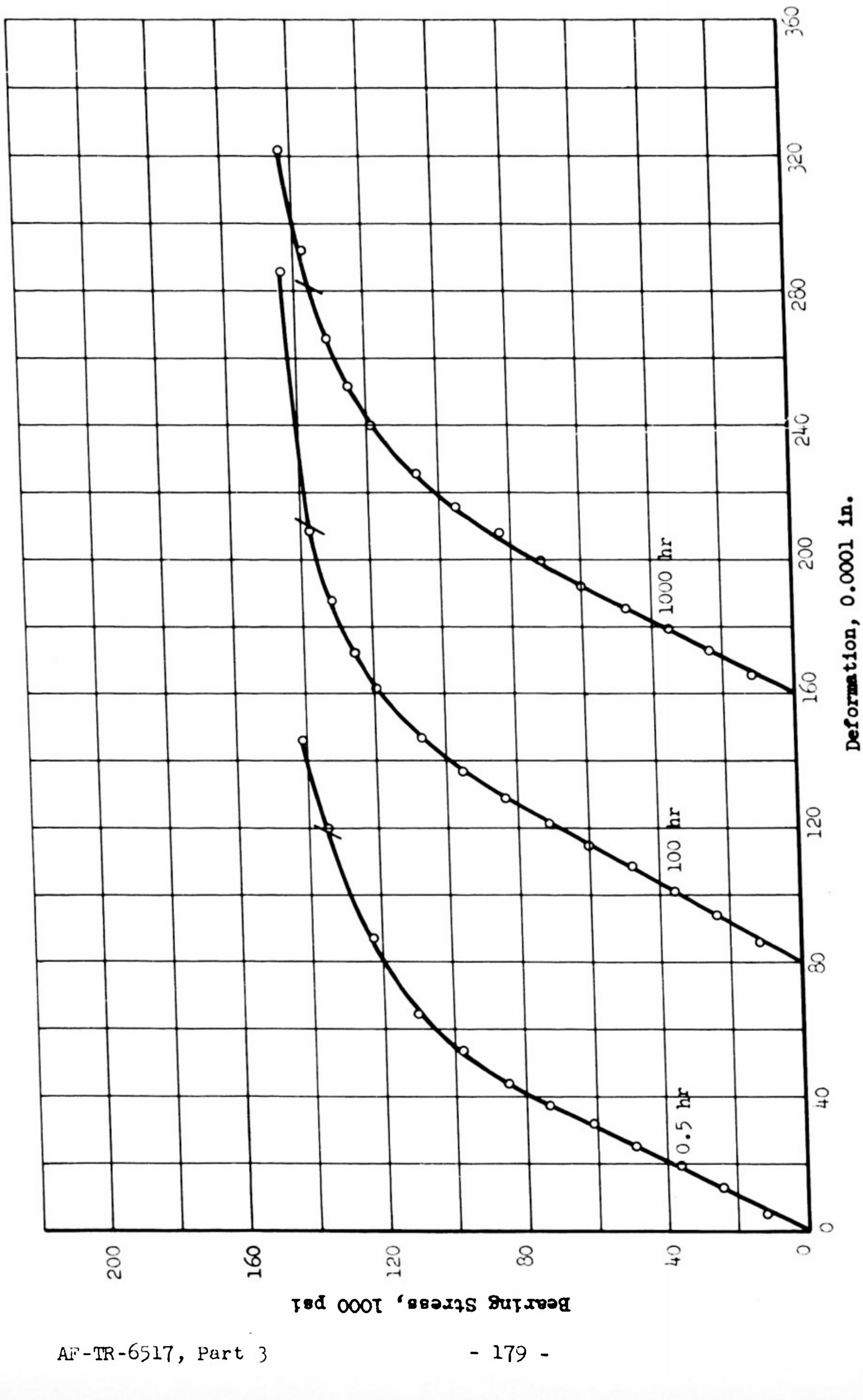

Fig. C-65 BEARING STRESS-DEFORMATION CURVES FOR RC-130-A TITANIUM ALLOY AT 500°F

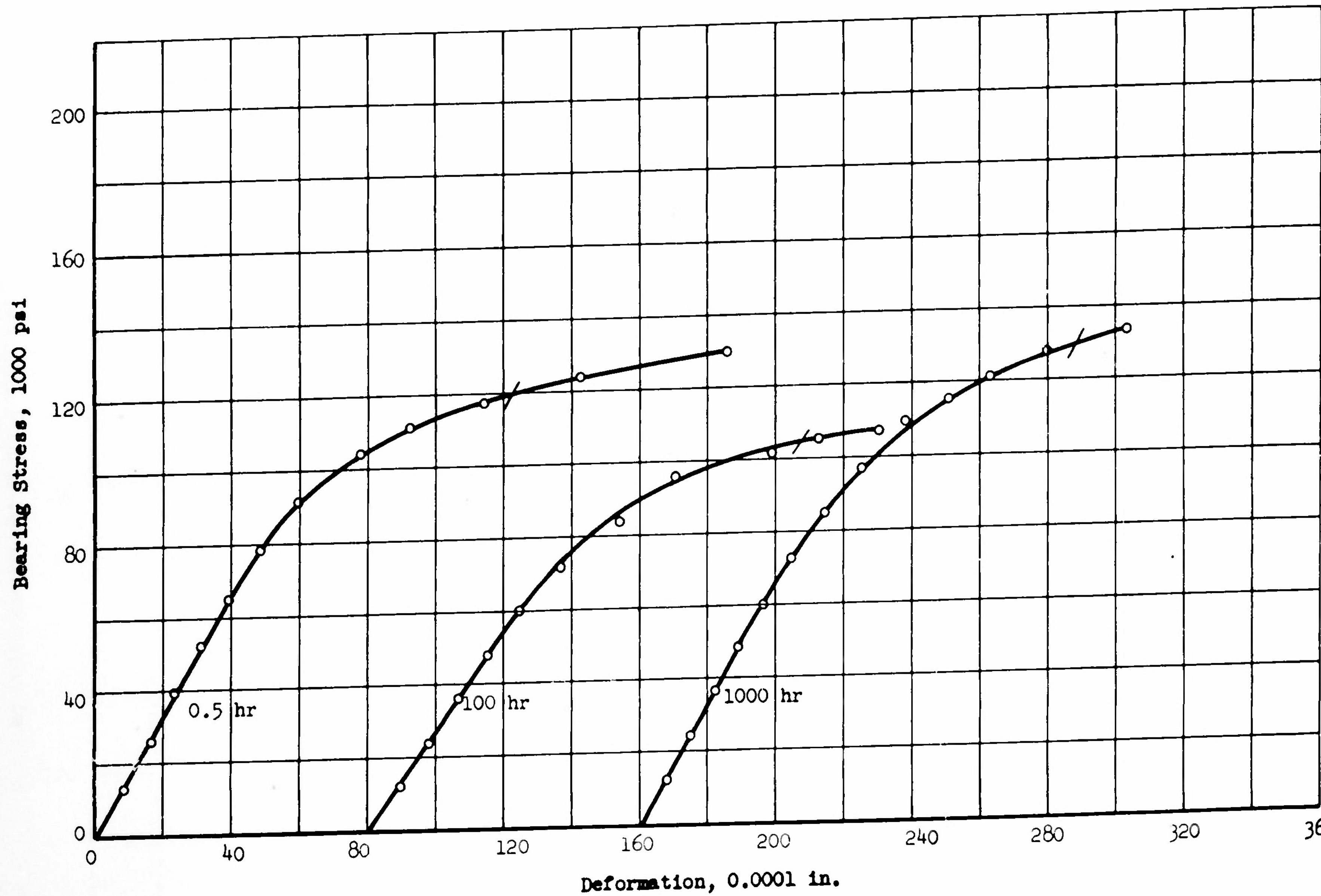

Fig. C-66 BEARING STRESS-DEFORMATION CURVES FOR RC-130-A TITANIUM ALLOY AT 600°F

APPENDIX D

COMPRESSIVE TANGENT MODULUS CURVES

Fig. D-1 TANGENT MODULUS VS COMPRESSIVE STRESS OF 14S-T6 ALUMINUM ALLOY AT ROOM TEMPERATURE

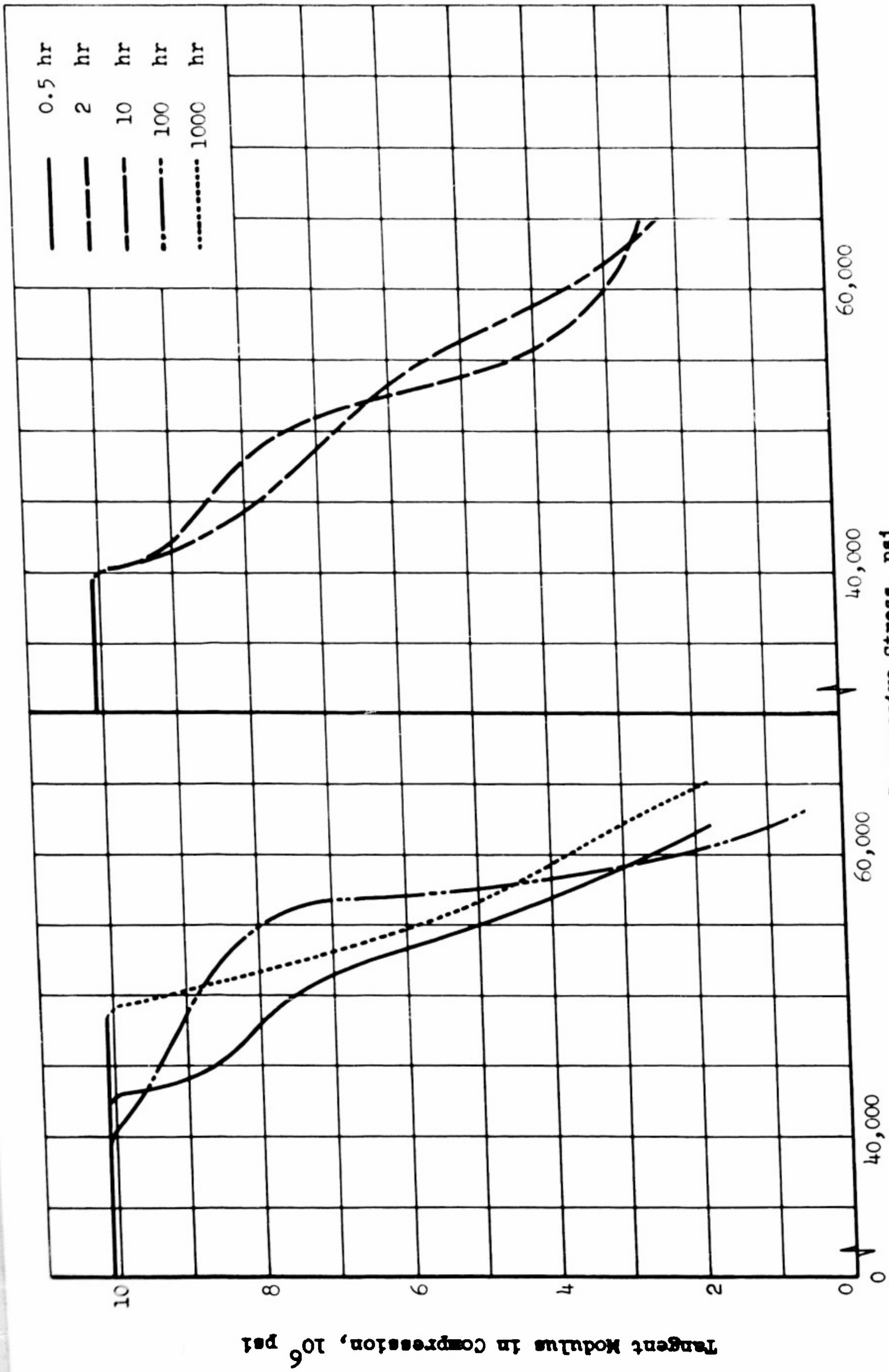

Fig. D-2 TANGENT MODULUS VS COMPRESSIVE STRESS OF 14S-T6 ALUMINUM ALLOY AT 200°F FOR VARIOUS EXPOSURE TIMES

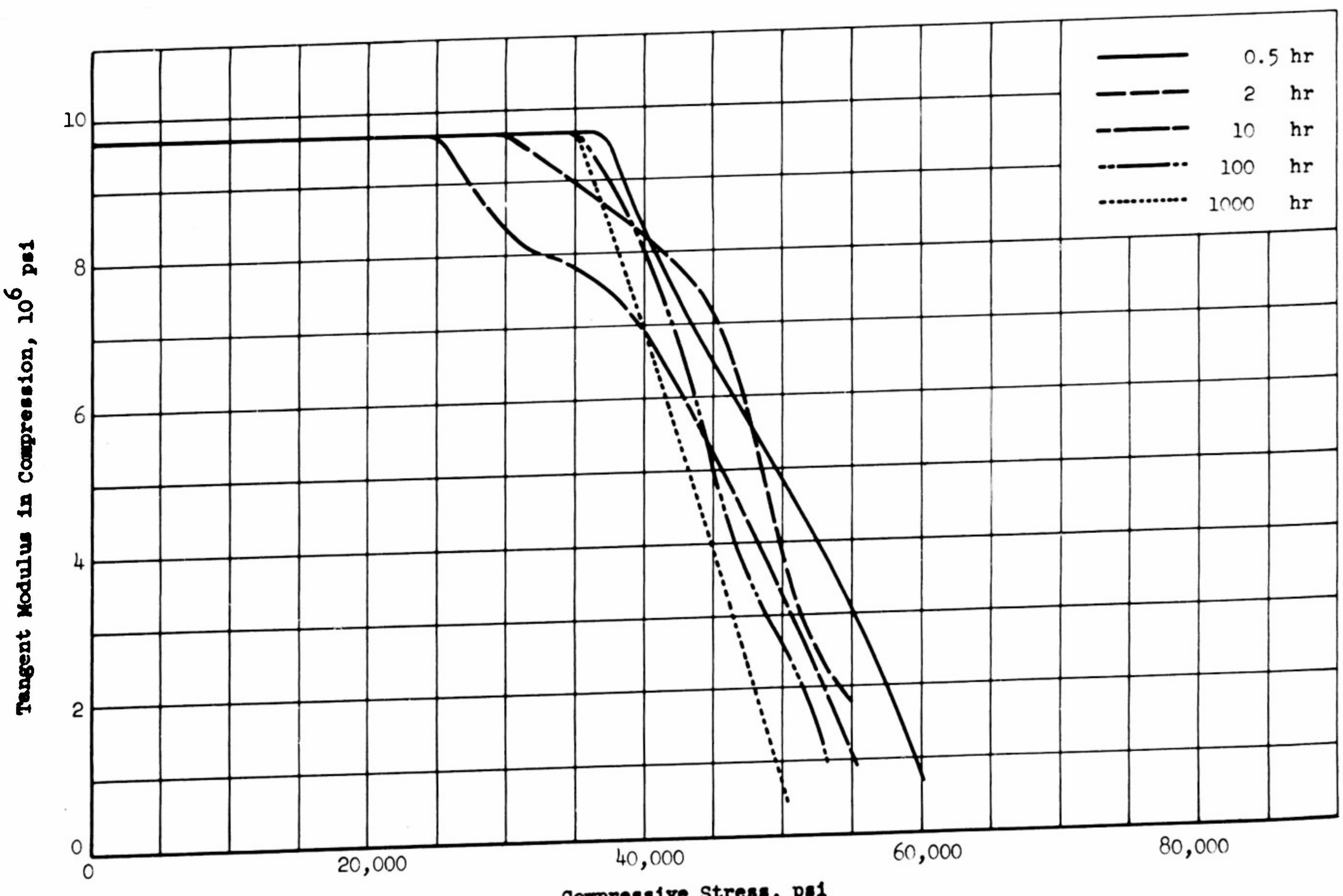

Fig. D-3 TANGENT MODULUS VS COMPRESSIVE STRESS OF 14S-T6 ALUMINUM ALLOY AT 300°F FOR VARIOUS EXPOSURE TIMES

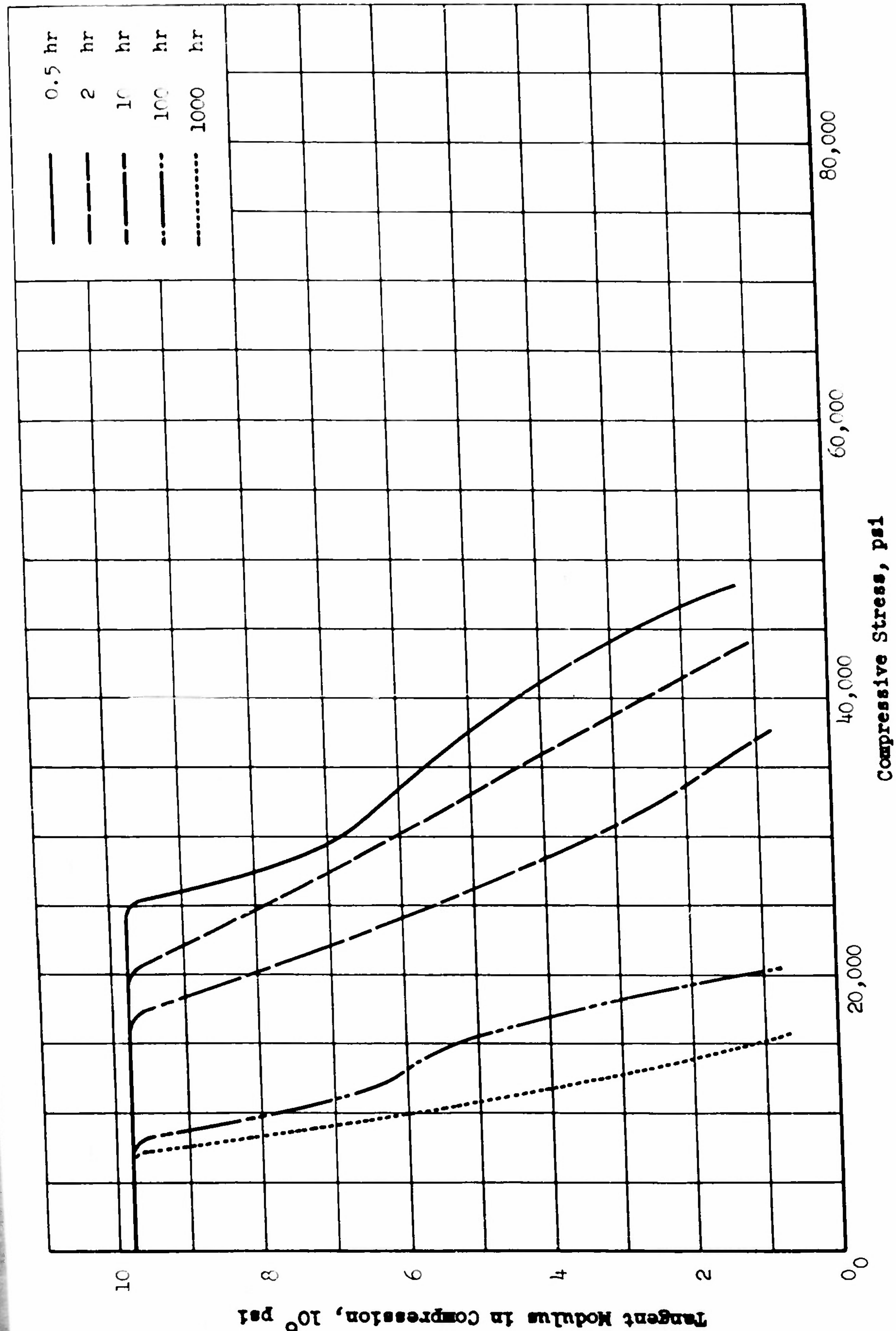

Fig. D-4 TANGENT MODULUS VS COMPRESSIVE STRESS OF 14S-T6 ALUMINUM ALLOY AT 400°F FOR VARIOUS EXPOSURE TIMES

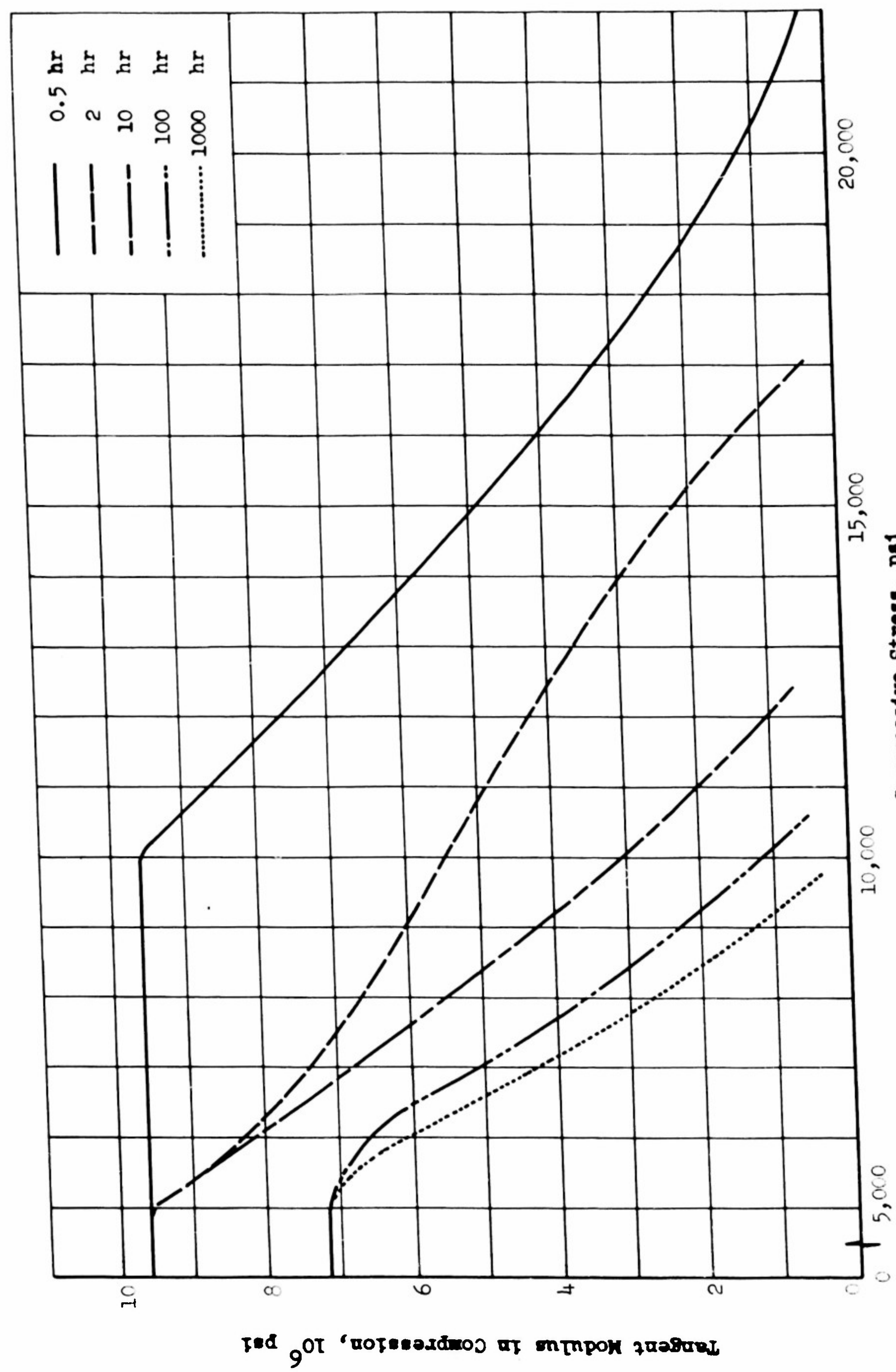

Fig. D-5 TANGENT MODULUS VS COMPRESSIVE STRESS OF 14S-T6 ALUMINUM ALLOY AT 500°F FOR VARIOUS EXPOSURE TIMES

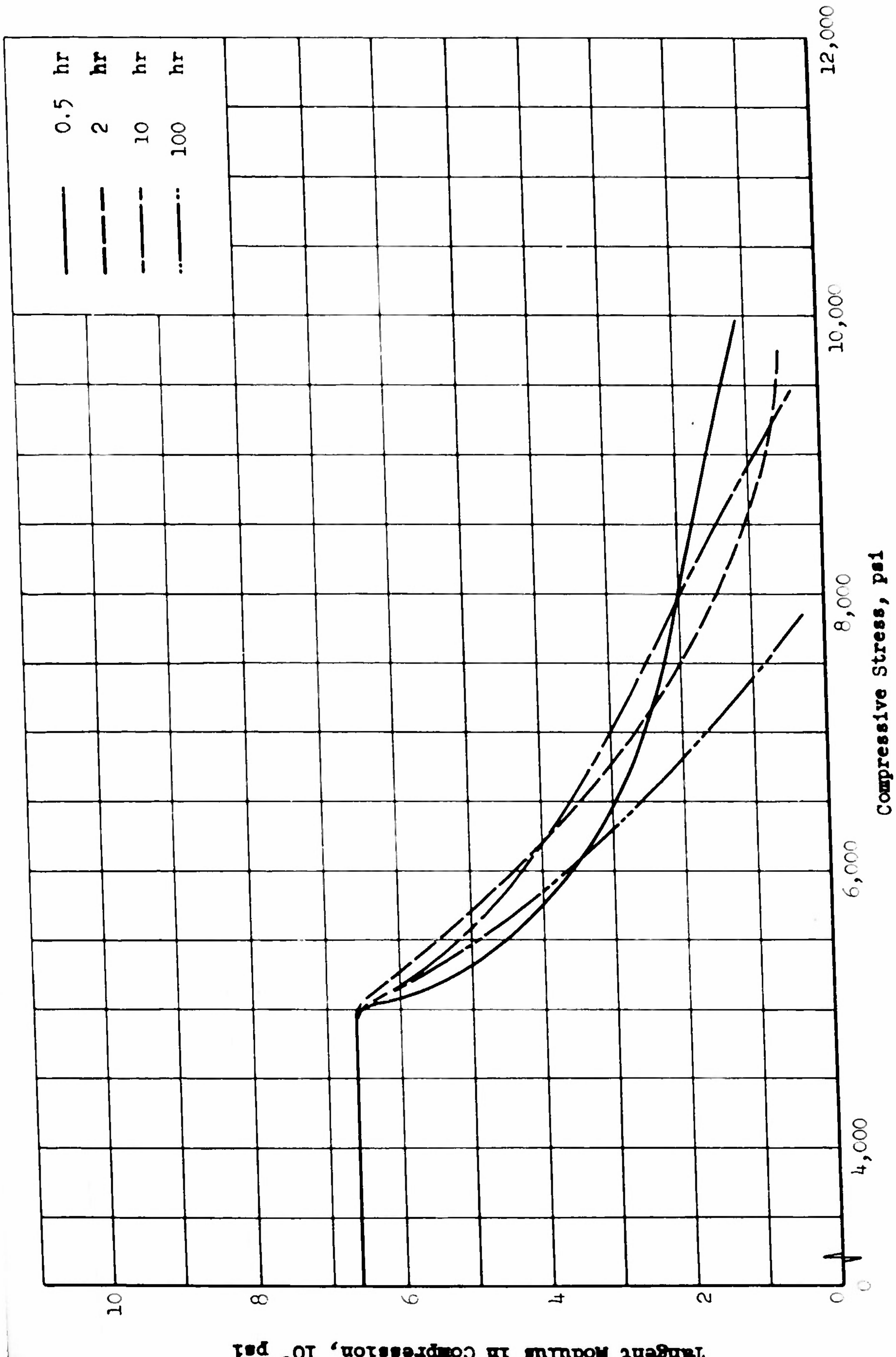

Fig. D-6 TANGENT MODULUS VS COMPRESSIVE STRESS OF 14S-T6 ALUMINUM ALLOY AT 600° F FOR VARIOUS EXPOSURE TIMES

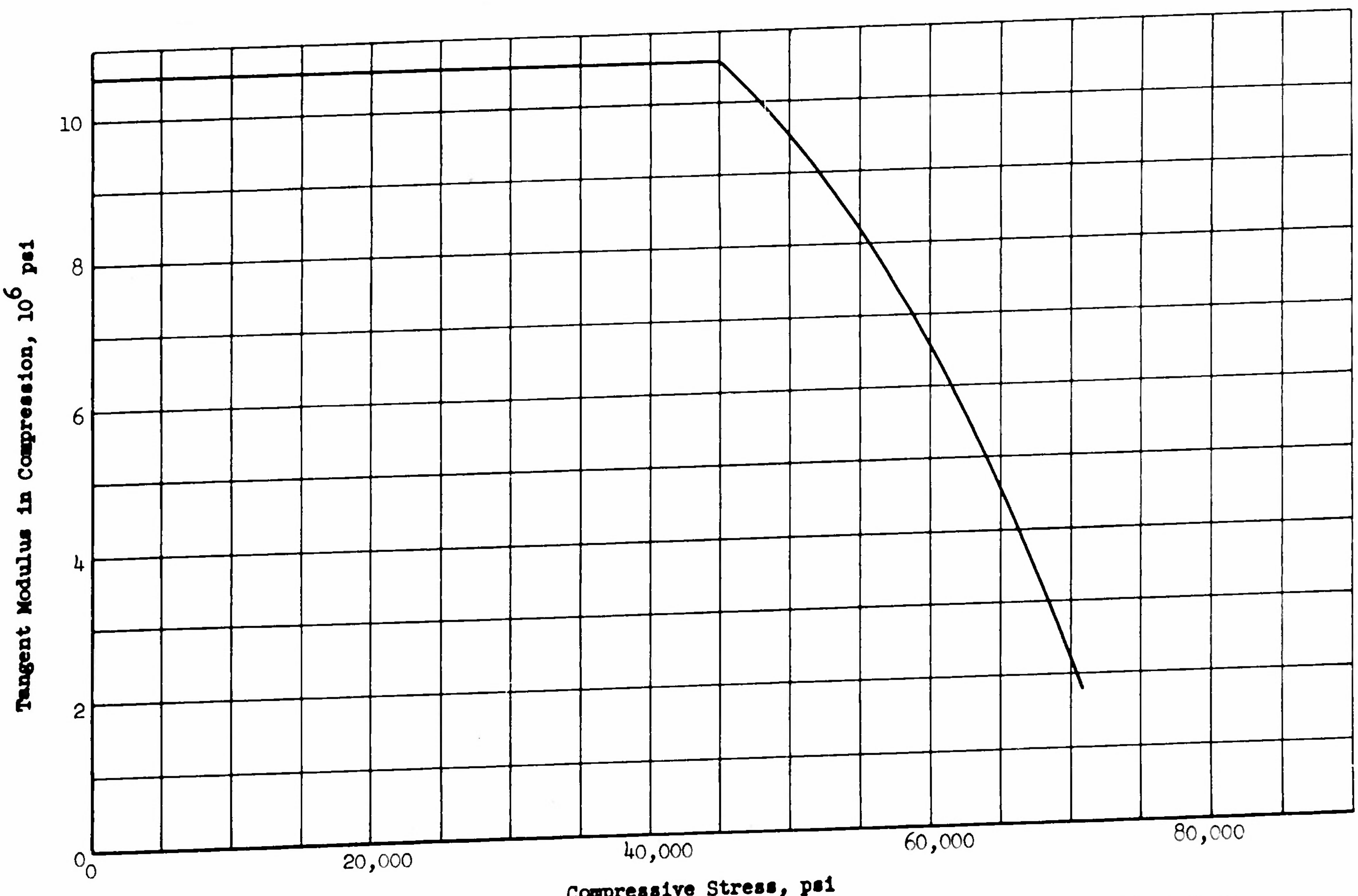

Fig. D-7 TANGENT MODULUS VS COMPRESSIVE STRESS OF 24S-T81 ALUMINUM ALLOY AT ROOM TEMPERATURE

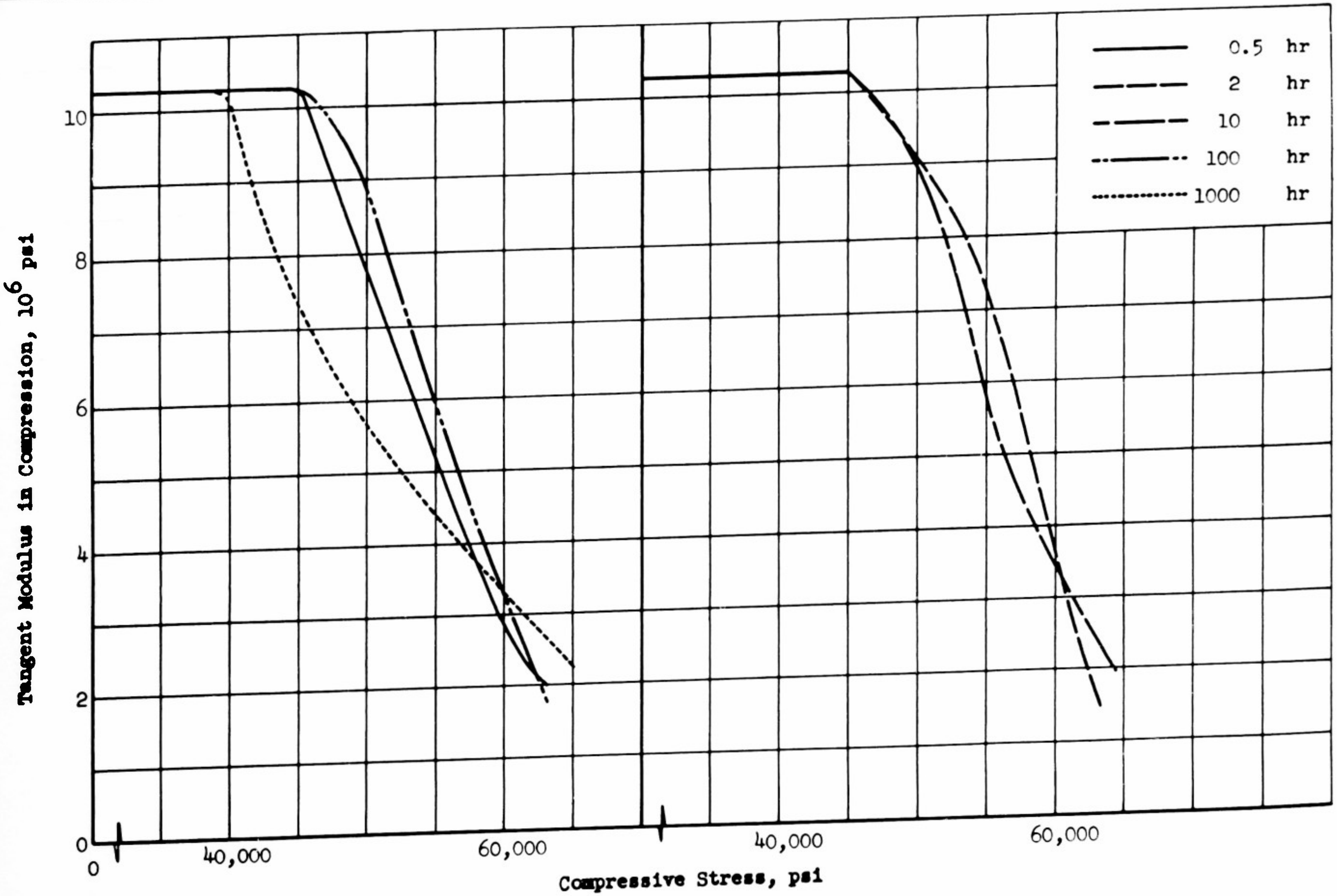

Fig. D-8 TANGENT MODULUS VS COMPRESSIVE STRESS OF 24S-T81 ALUMINUM ALLOY AT 200° F FOR VARIOUS EXPOSURE TIMES

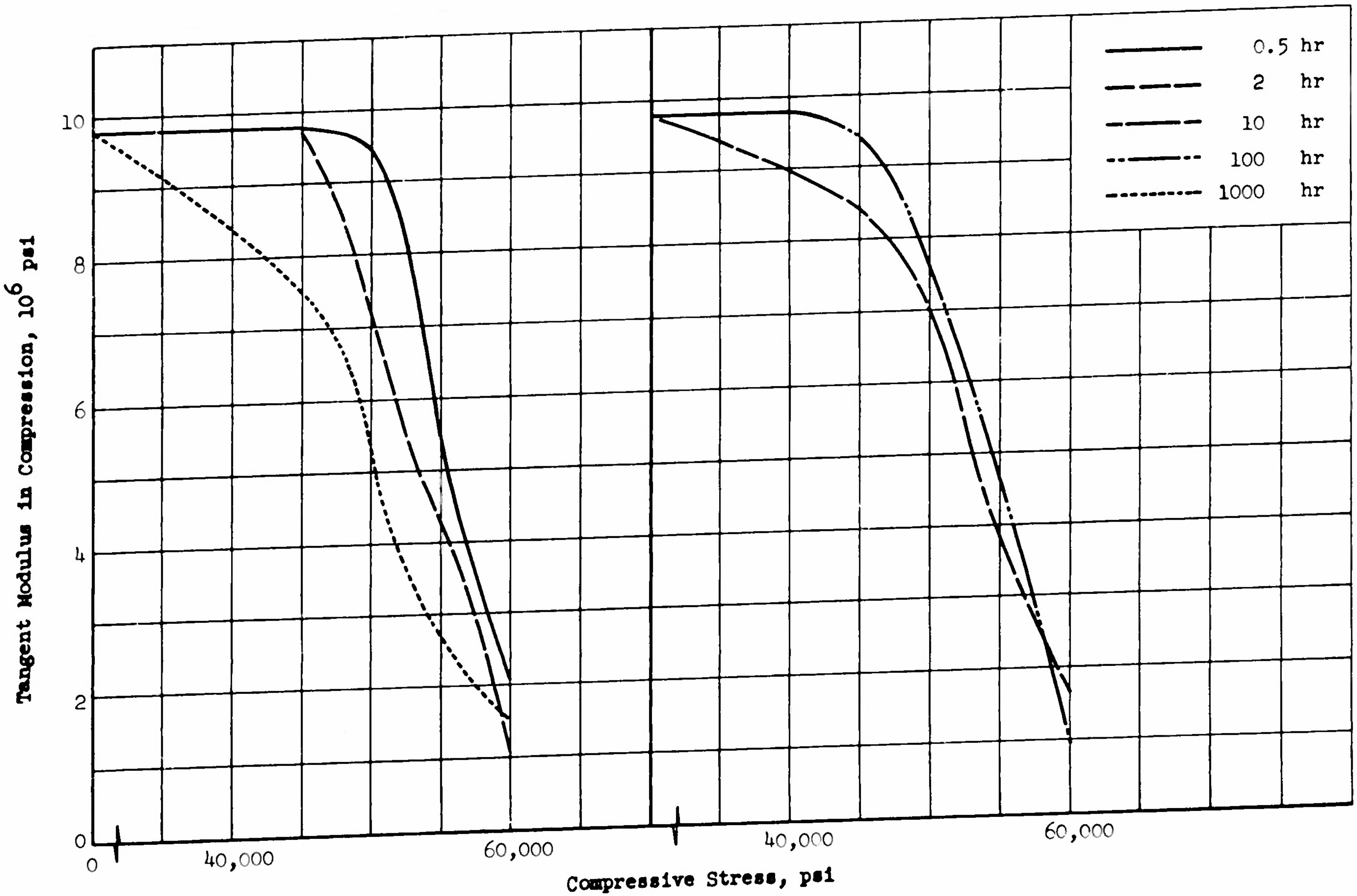

Fig. D-9 TANGENT MODULUS VS COMPRESSIVE STRESS OF 24S-T81 ALUMINUM ALLOY AT 300°F FOR VARIOUS EXPOSURE TIMES

Fig. D-10 TANGENT MODULUS VS COMPRESSIVE STRESS OF 24S-T81 ALUMINUM ALLOY AT 400°F FOR VARIOUS EXPOSURE TIMES

Fig. D-11 TANGENT MODULUS VS COMPRESSIVE STRESS OF 24S-T86 ALUMINUM ALLOY AT ROOM TEMPERATURE

Fig. D-12 TANGENT MODULUS VS COMPRESSIVE STRESS OF 24S-T86 ALUMINUM ALLOY AT 200°F FOR VARIOUS EXPOSURE TIMES

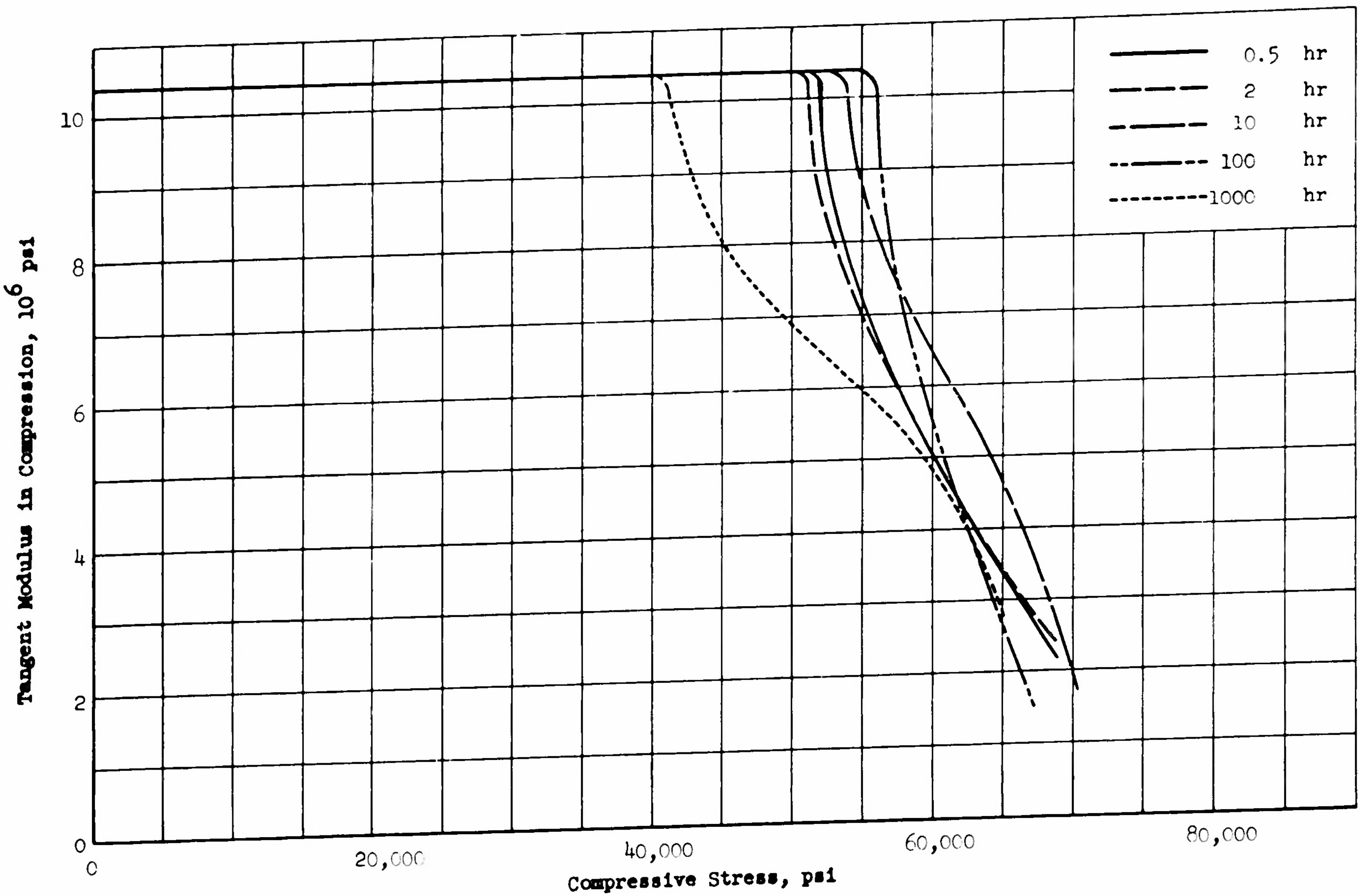

Fig. D-13 TANGENT MODULUS VS COMPRESSIVE STRESS OF 24S-T86 ALUMINUM ALLOY AT 300°F FOR VARIOUS EXPOSURE TIMES

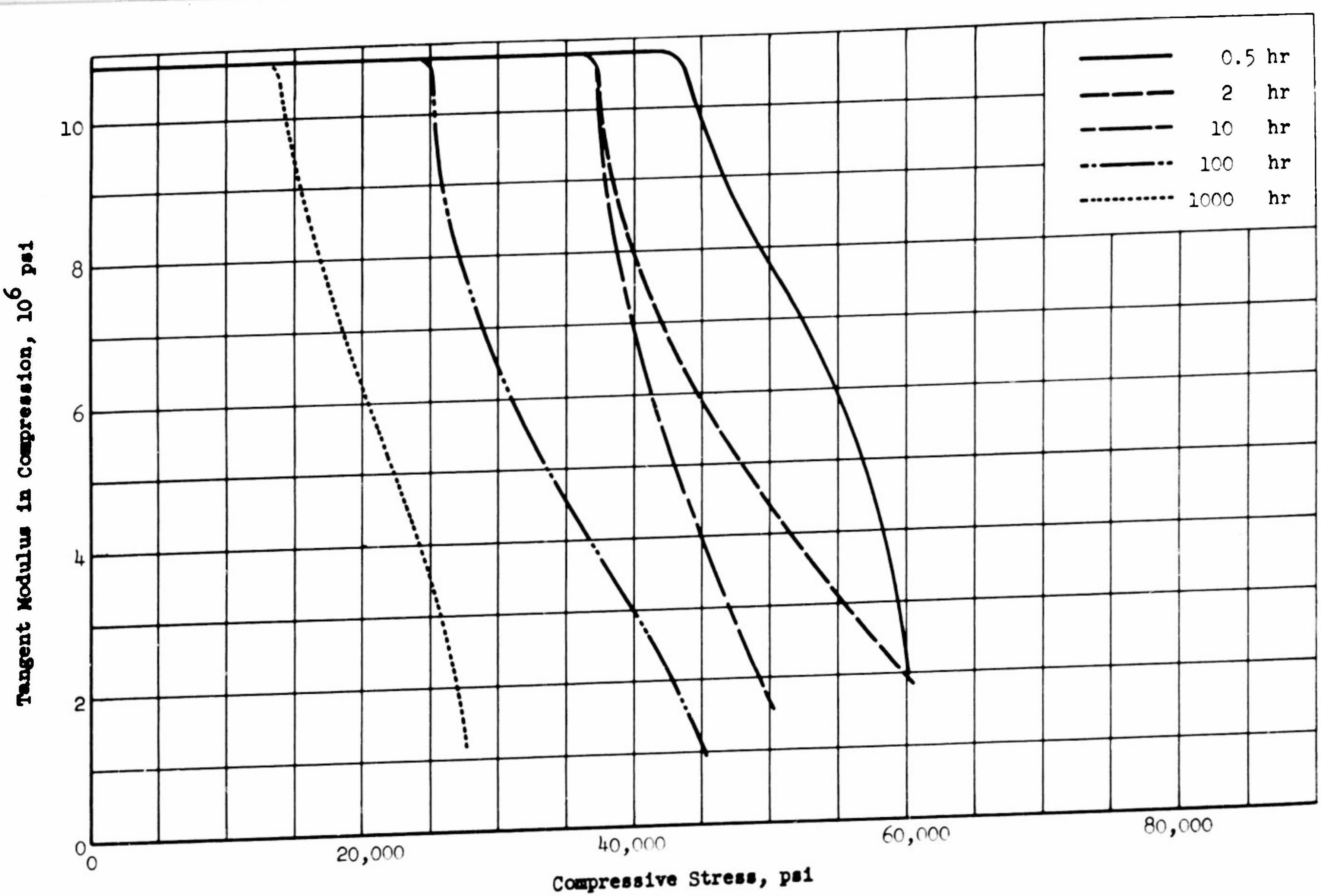

Fig. D-14 TANGENT MODULUS VS COMPRESSIVE STRESS OF 24S-T86 ALUMINUM ALLOY AT $400^{\circ}F$ FOR VARIOUS EXPOSURE TIMES

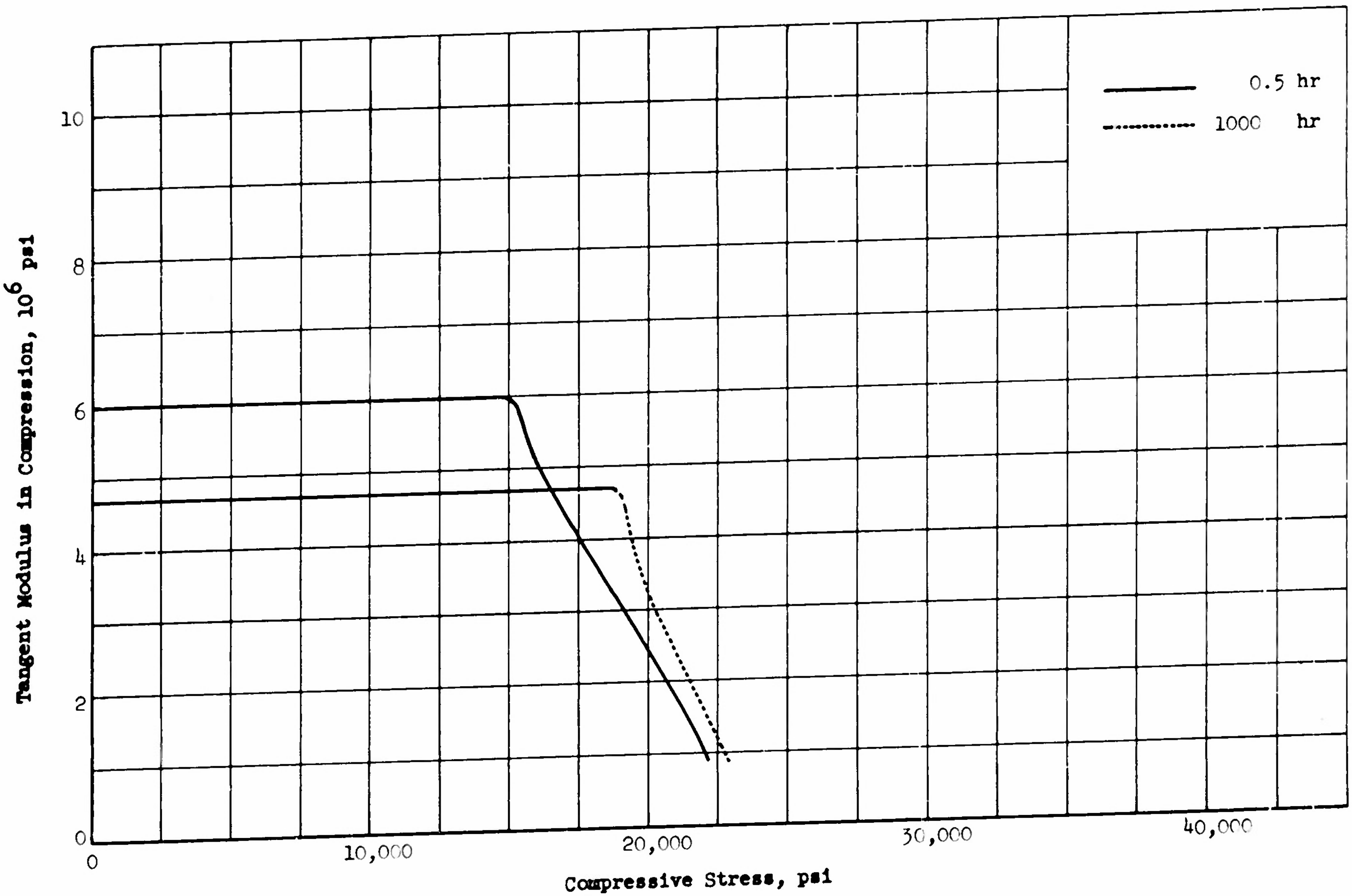

Fig. D-15 TANGENT MODULUS VS COMPRESSIVE STRESS OF FS1-H24 MAGNESIUM ALLOY AT 200°F FOR 0.5 AND 1000 HR EXPOSURE TIMES

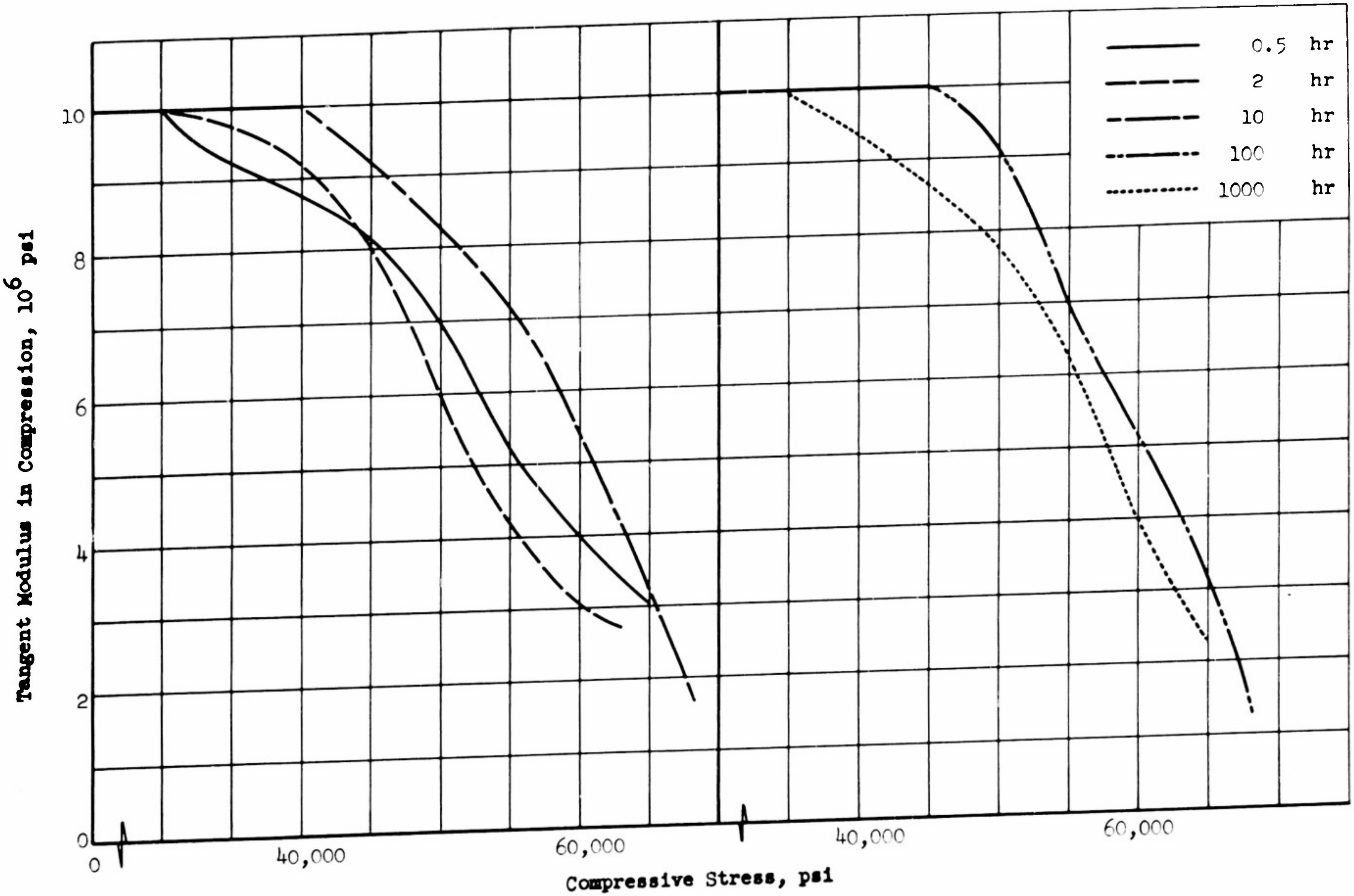

Fig. D-16 TANGENT MODULUS VS COMPRESSIVE STRESS OF 75S-T6 ALUMINUM ALLOY AT 200°F FOR VARIOUS EXPOSURE TIMES

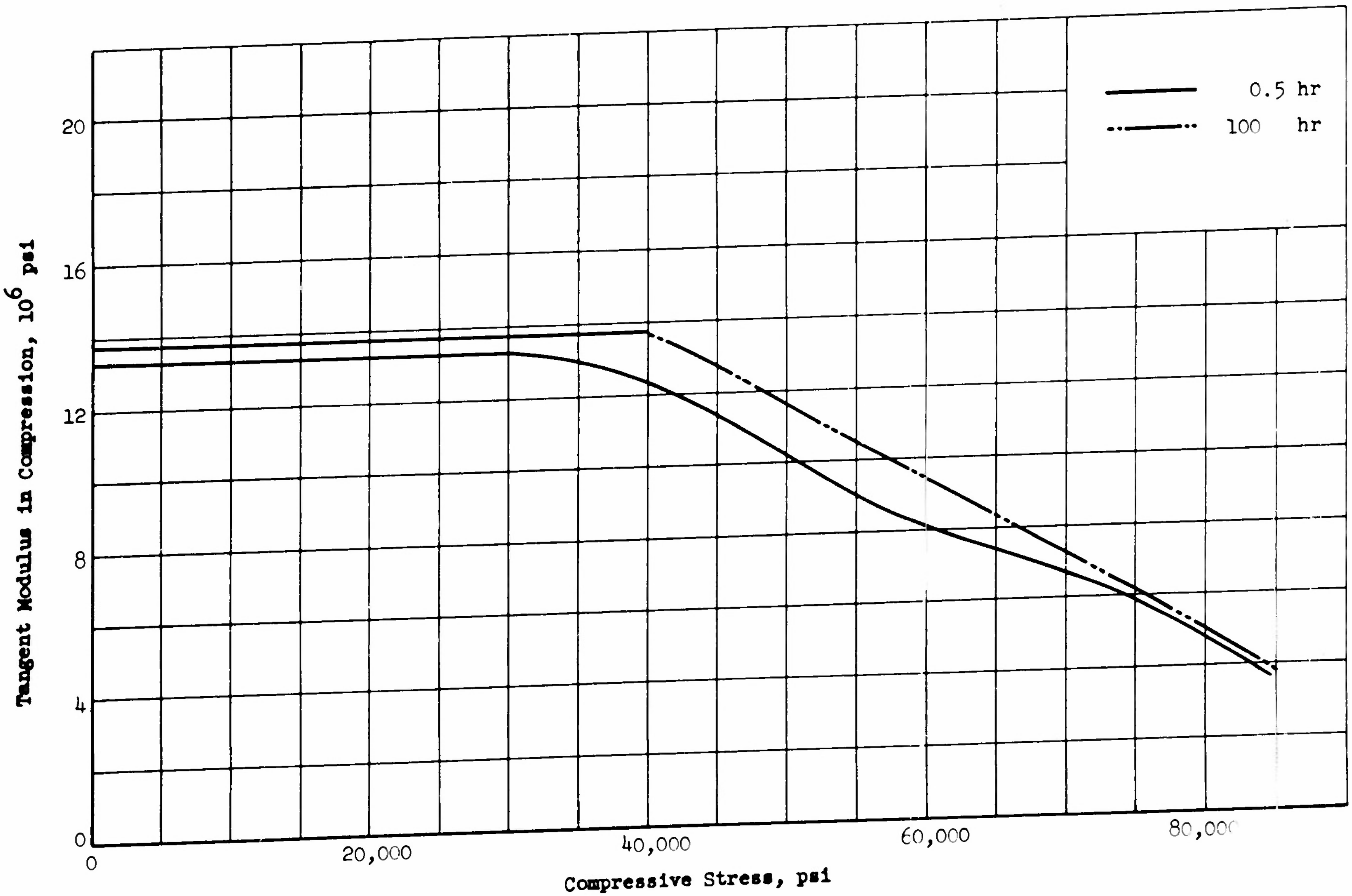

Fig. D-17 TANGENT MODULUS VS COMPRESSIVE STRESS OF COLD ROLLED TITANIUM AT 200°F FOR 0.5 AND 100 HR EXPOSURE TIMES

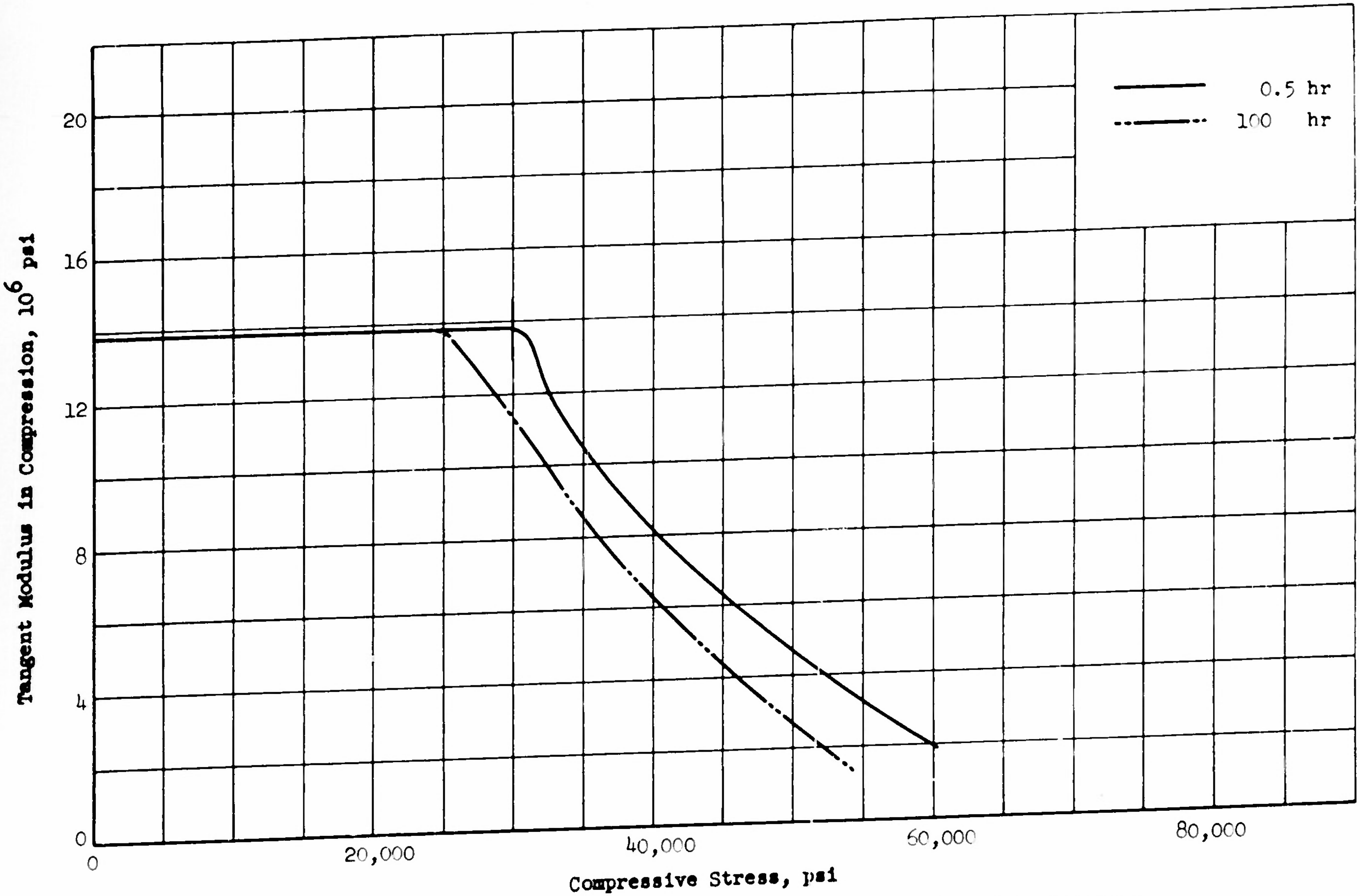

Fig. D-18 TANGENT MODULUS VS COMPRESSIVE STRESS OF ANNEALED TITANIUM AT 200°F FOR 0.5 AND 100 HR EXPOSURE TIMES

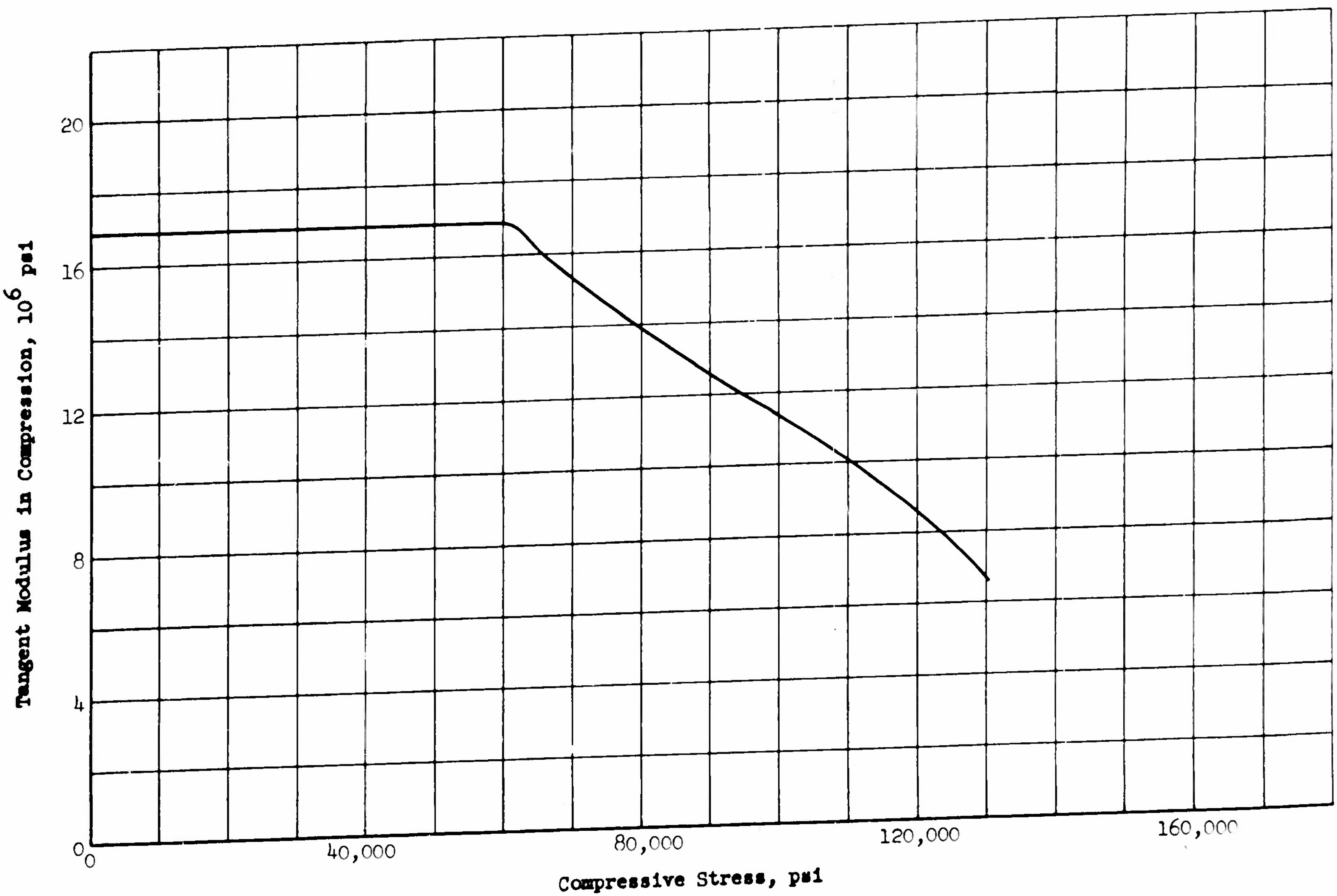

Fig. D-19 TANGENT MODULUS VS COMPRESSIVE STRESS OF RC-130-A TITANIUM ALLOY AT ROOM TEMPERATURE

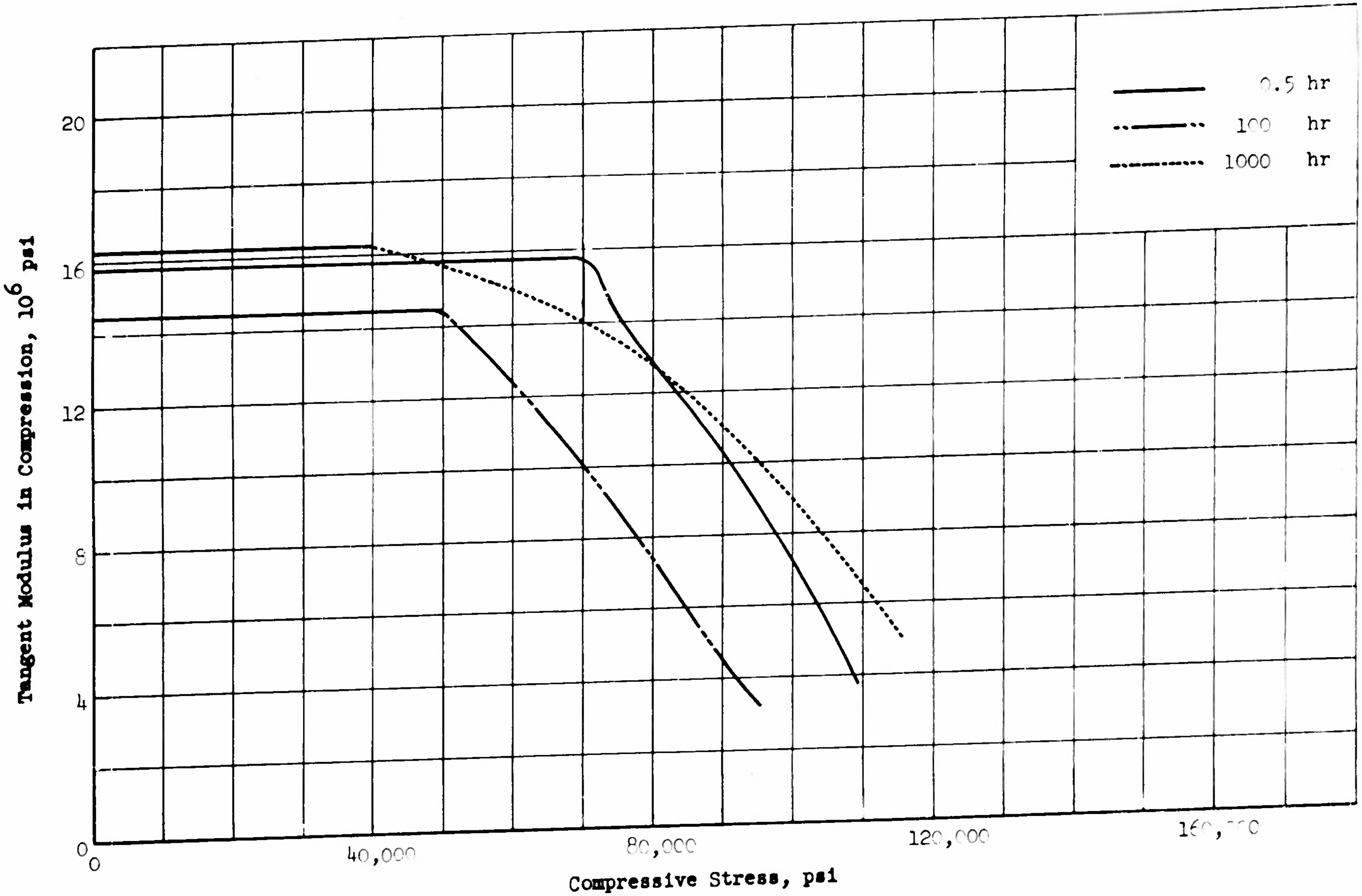

Fig. D-20 TANGENT MODULUS VS COMPRESSIVE STRESS OF RC-130-A TITANIUM ALLOY AT 300°F FOR VARIOUS EXPOSURE TIMES

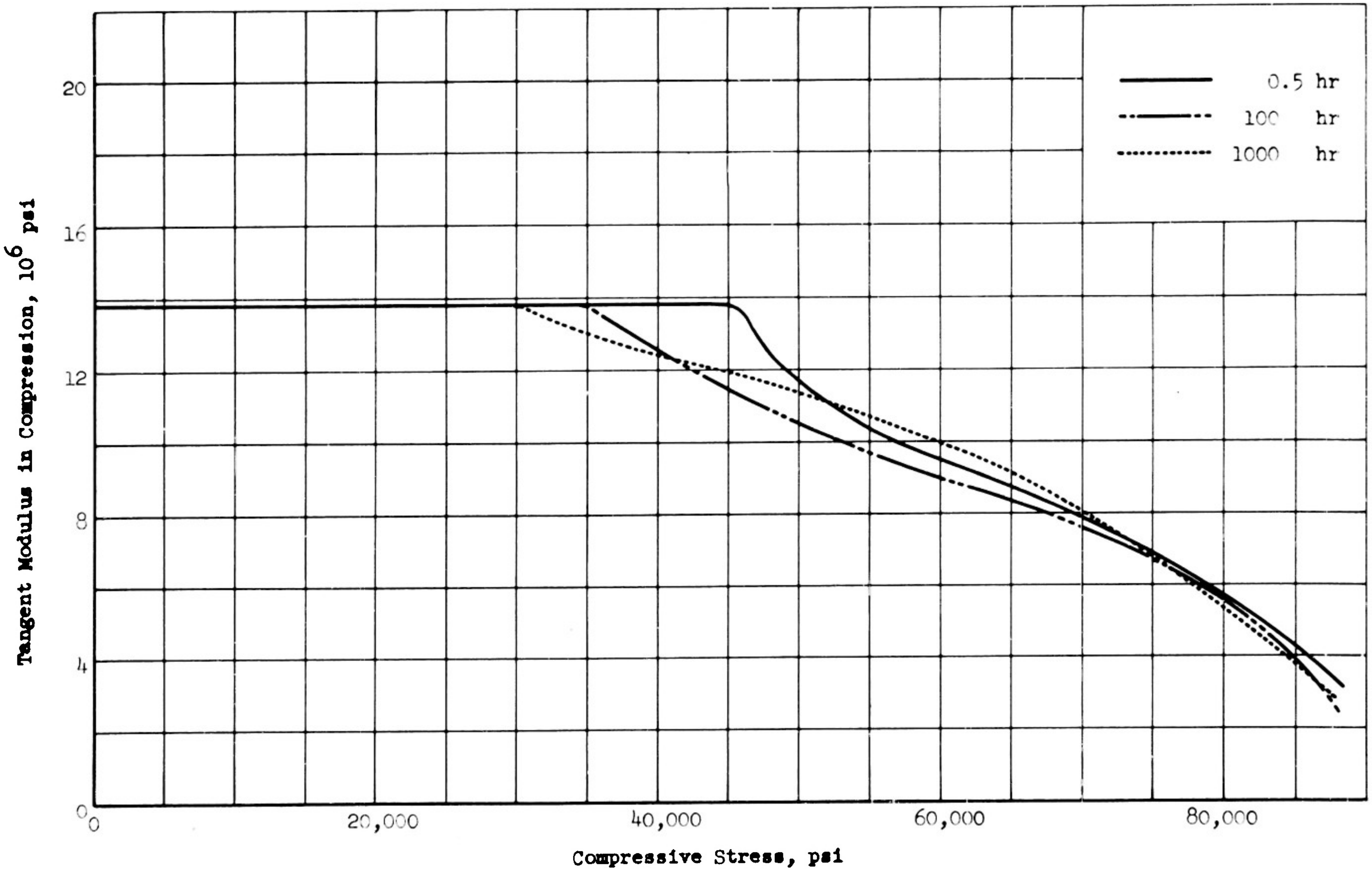

Fig. D-21 TANGENT MODULUS VS COMPRESSIVE STRESS OF RC-130-A TITANIUM ALLOY AT 500°F FOR VARIOUS EXPOSURE TIMES

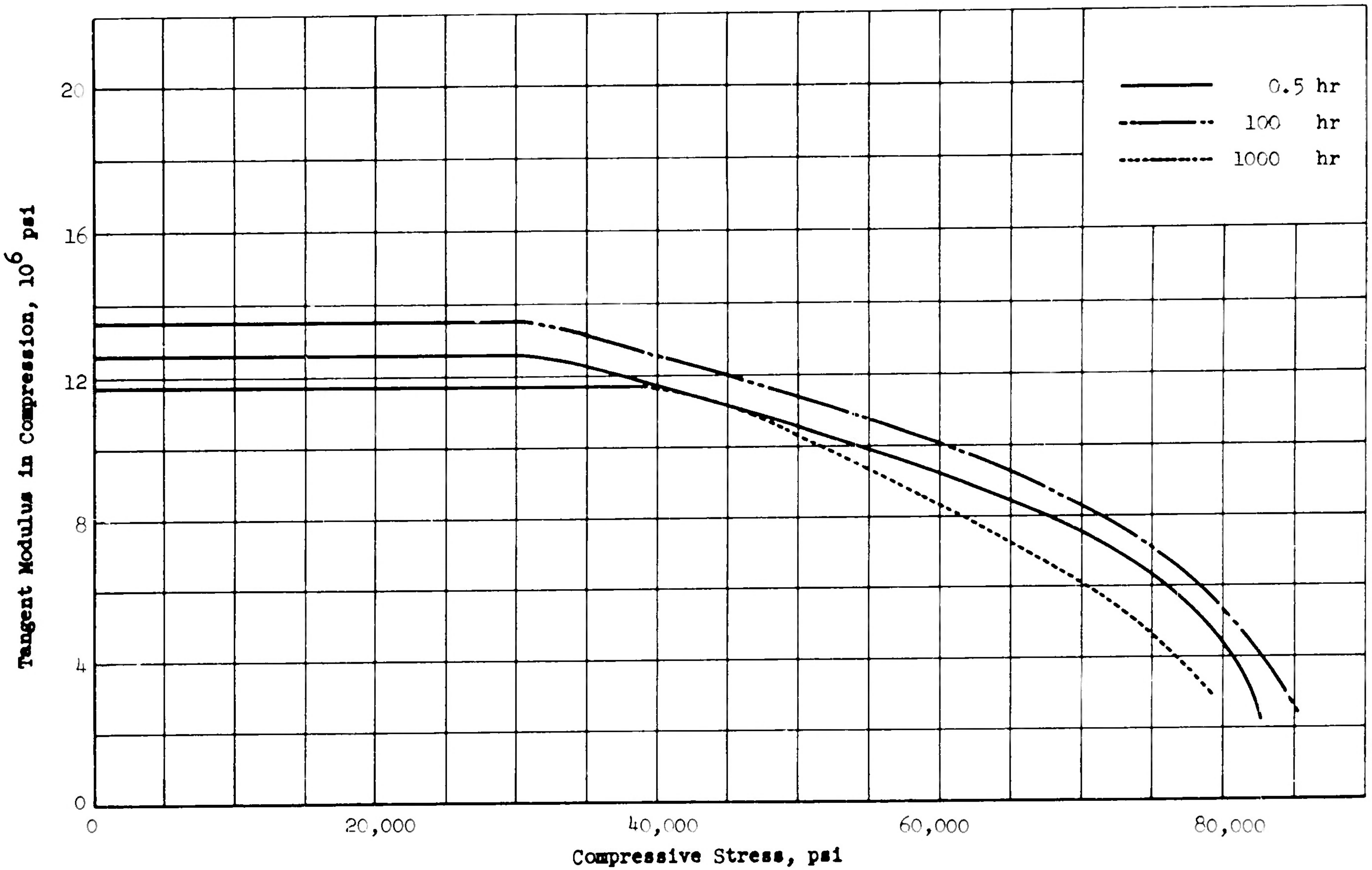

Fig. D-22 TANGENT MODULUS VS COMPRESSIVE STRESS OF RC-130-A TITANIUM ALLOY AT 600°F FOR VARIOUS EXPOSURE TIMES

APPENDIX E

PREVIOUS REPORTS ISSUED UNDER CONTRACT NO. AF33(038)-8681

APPENDIX E

PREVIOUS REPORTS ISSUED UNDER CONTRACT NO. AF33(038)-8681

I. AF Technical Report 6517, Part 1, "Determination of Physical Properties of Nonferrous Structural Sheet Materials at Elevated Temperatures," December 1951.

This report presents, tabular and graphical form, data from tests of the sheet materials listed below for the indicated temperature and exposure conditions.

Material	Temperature, °F	Exposure Time, hr
24S-T3 Aluminum Alloy	78, 212, 300, 400, 500, 600, 700	0.5, 2, 10, 100, 1000
75S-T6 Aluminum Alloy	78, 300, 400, 500, 600	0.5, 2, 10, 100, 1000
FS-1H Magnesium Alloy	78, 300, 400, 500, 600	0.5, 2, 10, 100, 1000
MH Magnesium Alloy	78, 300, 400, 500, 600	0.5, 2, 10, 100, 1000
Annealed Titanium	78, 400, 600, 800, 1000	0.5, 100
Cold Rolled Titanium	78, 400, 600, 800, 1000	0.5, 100

For each of the above conditions, data on the following properties of 0.064-inch sheet is presented in tabular form:

1. Compressive Yield Stress (0.2% offset)
2. Modulus of Elasticity in Compression
3. Bearing Yield Stress
4. Ultimate Bearing Stress
5. Tensile Yield Stress (0.2% offset)
6. Tensile Ultimate Stress
7. Modulus of Elasticity in Tension

Tabulated data on two properties of specimens cut from 3/16-inch sheet is also included:

8. Ultimate Tensile Stress

9. Ultimate Shear Stress of 0.125-inch Diameter Specimen

Numerous graphs are presented which illustrate the variation of these properties as functions of temperature and exposure time. A tangent modulus versus compressive stress curve is also included for each test condition.

II. AF Technical Report 6517, Supplement 1, "Determination of the Physical Properties of Ferrous and Nonferrous Structural Sheet Materials at Elevated Temperatures," March 1952.

This volume presents typical tensile and compressive stress-strain curves and bearing stress-deformation curves for the materials and conditions covered in AF Technical Report 6517, Part 1. One curve is drawn for each test condition.

III. AF Technical Report 6517, Part 2. "Determination of the Physical Properties of Ferrous and Nonferrous Structural Sheet Materials at Elevated Temperatures," December 1952.

This report contains data in tabular and graphical form from tests of the sheet materials listed below for the indicated temperature and exposure conditions.

Materials	Temperature, °F	Exposure Time, hr
XA78S-T6 Aluminum Alloy	78, 212, 300, 400, 500, 600	0.5, 2, 10, 100, 1000
FS-1a Magnesium Alloy	78, 300, 400, 500, 600	0.5, 2, 10, 100, 1000
SAE8630 Alloy Steel,		
125,000 psi tensile	78, 400, 600, 800, 1000, 1200	0.5, 2, 10, 100
180,000 psi tensile	78, 400, 600, 800, 1000, 1200	0.5, 2, 10, 100
SAE4130 Alloy Steel	78, 400, 600, 800, 1000, 1200	0.5, 2, 10, 100
302 Stainless, Annealed	78, 400, 600, 800, 1000, 1200	0.5, 2, 10, 100
301 Stainless, Half-Hard	78, 400, 600, 800, 1000, 1200	0.5, 2, 10, 100

For each of the above conditions, data on the following properties of 0.064-inch sheet is presented in tabular form:

1. Compressive Yield Stress (0.2% offset)
2. Modulus of Elasticity in Compression
3. Bearing Yield Stress
4. Ultimate Bearing Stress
5. Tensile Yield Stress (0.2% offset)
6. Tensile Ultimate Stress
7. Modulus of Elasticity in Tension

Tabulated data on two properties of specimens cut from 3/16-inch sheet is also included:

8. Ultimate Tensile Stress
9. Ultimate Shear Stress of 0.125-inch Diameter Specimens

The report contains graphs which show the variation of the above properties as functions of temperature and exposure time. In addition, a typical tangent modulus versus compressive stress curve, compressive stress-strain curve, tensile stress-strain curve, and bearing stress-deformation curve is presented for each test condition.

DEM/edit/kf